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Moving People in the Future: Land passenger transport and "new" mobility technology

Bus and Coach Industry
Policy Paper 11

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Moving People in the Future: Land passenger transport and “new” mobility technology

Authors:

Adjunct Professor John Stanley, Institute of Transport and Logistics Studies, Business School, University of Sydney

Professor David Hensher FASSA, PhD, Institute of Transport and Logistics Studies, Business School, University of Sydney

Yale Wong, Doctoral Candidate and Research Analyst, Institute of Transport and Logistics Studies, Business School, University of Sydney

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Abstract

Changing societal values and emerging new technologies are increasing the probability of massive shifts in transport service offerings in coming decades, with potentially huge benefits and/or costs.

This Paper explores socio-economic trends and their interaction with new technologies, largely by developing optimistic and pessimistic scenarios about how the future of land passenger transport might emerge in coming years. In particular, the Paper discusses how Mobility-as-a-Service and AEVs might impact public transport service provision, distinguishing between trunk and local service offerings. It suggests that trunk public transport services will remain important components of urban passenger transport networks, because of the wider economic benefits that these services release, particularly in bigger cities. Concerns are expressed, however, about low volume local public transport services, the main value from which is social inclusion. Policy measures to help ensure that emerging transport technologies are net contributors to social welfare are outlined, including transport pricing reform, urban land use/transport planning to promote more compact towns and cities and to slow urban sprawl, together with shared mobility contracts to support social inclusion from local transport.

Foreword

This research Policy Paper is part of a policy series of publications aimed at decision and policy makers, academics and students.

This Policy Series focuses on land transport, land use, integrated planning and urban development challenges in Australia.

The Policy Series has been developed by the Bus Industry Confederation (BIC) of Australia and the Institute of Transport and Logistics Studies, Business School, University of Sydney, and addresses specific subject matters and issues raised in the BIC's initial two major policy reports *(Solutions for a Growing Australia* and *Solutions for a Liveable Australia),* together with emerging policy concerns. All publications are available at www.ozebus.com.au.

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1. Scope

> *We are on the cusp of one of the fastest, deepest, most consequential disruptions of transportation in history. By 2030, within 10 years of regulatory approval of autonomous vehicles (AVs), 95% of U.S. passenger miles traveled will be served by on-demand autonomous electric vehicles owned by fleets, not individuals, in a new business model we call "transport-as-a-service" (TaaS).* (RethinkX 2017, p. 6)

Commentary on how land passenger transport's future will evolve spans the evolutionary-revolutionary range, with the recent RethinkX (2017) position probably the most radical. That paper presages massive disruption to value chains, stranded assets, job losses in traditional transport occupations and plummeting oil prices, along with vast new business opportunities, driven by the introduction of autonomous electric vehicles (AEVs). The well-researched business case they build for this future reads in compelling fashion.

At the more evolutionary end, commentators such as Corman et al. (2015) and Litman (2018) envisage gradual introduction of new technologies that improve the customer experience, such as improvements in demand-responsive transport opportunities for the first mile-last mile of public transport travel, with widespread adoption of autonomous vehicles (AVs) three or so decades away. The growing interest in Mobility-as-a-Service (MaaS) spans this range of possibilities over time, with the initial focus being on improvements in the convenience of customer travel choices but with longer term possibilities being inextricably linked to what happens with AVs.

Uncertainty is a key characteristic that envelopes any discussion of how future transport systems will emerge, following many decades in which change has generally been slow. These uncertainties relate, for example, to matters such as how, and how quickly, technologies develop, the way they will be received by consumers, how governments decide to react (or not) and the range of matters that bear on these questions.

In terms of the scope of the present Paper, we consider some of the main technological influences or disruptions that are likely to shape the future of land passenger transport and how these disruptions might interface with a number of economic, social and environmental trends to affect life chances and the quality of the environment upon which such chances depend. We also explore opportunities that might be available to governments to help ensure that the outcomes from these forces enhance, rather than reduce, societal wellbeing.

This Paper is inevitably set in a context dominated by 'Rumsfeldian' known/unknown unknowns. It limits itself to land passenger transport, though we acknowledge the third dimension (e.g., freight/passenger drones) as espoused by some proponents. It stays clear of matters about which we have little knowledge or understanding, such as privacy considerations and cyber security. We recognize these are important and need to be resolved if AVs are to be net contributors to societal wellbeing but they are matters beyond our fields of expertise.

In Section 2 we summarise our understanding of the major technological trends that are disrupting land passenger transport, or are likely to do so in coming years. In particular, we consider:

- smartphone apps, reflected in the rapid emergence of familiar businesses such as Uber, Lyft and Ola and, by extension, integrated travel platforms commonly known as mobility as a service (MaaS)
- autonomous vehicles (AVs), perhaps the subject of greatest interest in the literature because of their disruptive potential, and where some trials are taking place in Australia and overseas (of both cars and small buses)
- electric vehicles (EVs), including autonomous electric vehicles (AEVs), which form much of the base for the future visioning by RethinkX (2017), with accelerated impacts extending through both the transport and energy sectors, through opportunities in distributed energy.

The discussion in Section 2 introduces some potential benefits and costs of the technologies being considered.

Section 3 of this Paper considers key societal trends in greater detail. Accentuating the potential impacts of technological disruption on some of these trends is the current high rate of population growth being experienced in some of our major cities, driven in significant part by a high rate of overseas migration, which is a policy variable rather than socio-economic trend. Population growth is not the major focus of the Paper but a high population growth rate will amplify some of the potential consequences of technological disruption in land passenger transport. For example, the faster the rate of population increase, ceteris paribus, the greater the rate of urban sprawl that will result, with its associated adverse consequences for traffic congestion, greenhouse gas emissions and social exclusion, compounding pressures that are already inherent in AVs (as discussed in Section 5 of this report).

Section 4 then sets out generic criteria that we suggest can indicate whether societal wellbeing is likely to be improved or worsened by major changes, such as the technological disruptions discussed in Section 2. This is ultimately a matter of value judgement but we are heartened to observe that there is widespread support internationally in land use transport policy and planning for triple bottom line (economic, social and environmental) approaches to assessing changes in societal wellbeing, complemented by governance arrangements that help assure alignment with desired outcomes. Integrated planning and policy approaches are central.

Assessing how technological disruptions might impact on societal wellbeing requires some understanding of major socio-economic and environmental trends against which these disruptions are likely to be taking place. In Australia's case, such trends are outlined in Table 1.1.

Table 1.1 Impacts of technological disruption on major socio-economic and environmental trends in Australia.

Growth of the knowledge economy and its spatial manifestations (with knowledge intensive jobs increasingly concentrating in inner urban areas and suburban business parks).
Growing interest in the sharing economy, reflected in areas such as accommodation and travel opportunities (e.g., car sharing, ride sharing).
Land use transport integration policy and the focus on achieving more compact settlement patterns, mitigating urban sprawl.
Dependence on the car. The high and increasing costs of our heavy dependence on motorised transport – these costs including congestion, air pollution, safety, health costs and the costs of increasing obesity levels, from a lack of exercise.
An ageing population, with generally a high level of car dependence but associated risks of mobility-related social exclusion as people attain older ages.
Climate Change and the associated imperative for Australia to substantially reduce its greenhouse gas emissions.
Growing inequality, with disadvantaged groups often located in outer urban or rural settings, where opportunities and services are more limited, including public transport services.

Section 5 brings the discussions in Sections 3 and 4 together by developing two scenarios to reflect how emerging technologies might impact societal wellbeing in coming years, drawing in part on what Isaac (2016) calls dystopian and utopian views, Cervero et al. (2017) call optimistic and pessimistic views and on contributions from a number of other authors in the field, such as Mervis (2017) and McKinsey Bloomberg NEF (2016). Considering these scenarios in light of the criteria for improved societal wellbeing discussed in Section 4 leads to the development, in Section 6, of policy proposals to manage the technological disruptions that have been considered, with a view to increasing the prospects for better outcomes. The high levels of uncertainty that pervade the subject mean that these policy implications must remain somewhat tentative but we see this as more a matter of when rather than if, insofar as it relates to the technological disruptions being discussed.

2. Disruptive technological changes affecting land passenger transport

2.1 Scope

A wide range of subjects could be considered under this section heading. We have limited our focus to a small number of matters that we see as having the potential to be game changers in terms of future land passenger mobility opportunities and impacts, either good or bad. The matters on which we focus are:

- smartphone based apps and shared business models that depend thereon, including mobility as a service (MaaS). This area is having an impact already but that impact could grow exponentially under the added impact of the following two areas of technological change
- autonomous vehicles (AVs), with potentially huge long term benefits in store, or costs, depending on the development pathway
- electric vehicles (EVs), which are a reality already but at small scale. Adding this element to AVs opens up opportunities for much bigger impacts within the transport sector and adds opportunities for synergies that extend beyond transport, into matters such as distributed energy systems.

2.2 Smartphone based apps, shared mobility and MaaS

Social and economic factors that create market demand opportunities for shared mobility futures need a supply side response that enables realisation. Smartphone based apps provide a platform for this response, with applications now in place such as fleet-based car sharing (e.g., car2go), peer-to-peer ride-hailing (e.g., Uber), peer-to-peer car sharing (e.g., easyCar club) and ride sharing (e.g., BlaBlaCar) (McKinsey Bloomberg NEF 2016). Market penetration is typically low but growing fast in developed countries, where car ownership rates are high, with the prospect of offering a viable broadly-based alternative to own-your-own car-based mobility, including in developing countries, where rates of car ownership are currently low.

These various sharing models are extending the range of mobility choices available to consumers. In turn, this broader platform provides an opportunity for **mobility brokers** to emerge, packaging up a range of mobility options for sale to consumers in the form of Mobility-as-a-Service (MaaS) or Transport-as-a-Service (TaaS). MaaS/TaaS can be defined as a personalised, one-stop travel management platform digitally unifying trip creation, purchase and delivery across all modes (Wong et al. 2017). It is about shifting transportation based on asset ownership (i.e., purchase of cars) to where it can be consumed as a service.

Thus, for example, Helsinki's pioneering Whim (MaaS) service offers customers and potential customers app-based bundled taxi, public transport, car service and bike share on a pay-as-you-go basis or monthly plan, with customers able to tailor their own monthly plan (Hensher 2017). Various pilots with different levels of integration have been launched around the world including in Sweden, Germany, Austria, Finland, Italy, France, The Netherlands and the United Kingdom (Jittrapirom et al., 2017). Locally, MaaS Australia[1] and SkedGo[2] are trying to launch this concept with various transport operators and non-mobility partners.

In terms of customer take-up, stated choice experiments conducted in the Sydney context (Ho et al., 2018 and Appendix A herein) suggest that MaaS is most attractive to infrequent car users over non-users (i.e., sole public transport users) and daily car users. That is, MaaS is most desirable for people who have an underutilised vehicle asset, perhaps using public transport during the week and driving only on weekends. On average, around 47% of respondents (n=252) they estimate will subscribe to a MaaS plan.

On the service delivery side, Hensher (2017) points to the role for the MaaS operator as an entrepreneur to broker new types of service, overcoming the traditional constraints of spatial boundaries in public transport (particularly bus) contracting. A new suite of partnerships between specialised businesses are being proposed which go beyond the standard procurement procedures set by government. Naturally, there exists tension between whether regulation or free market initiative ought to take precedence in the development of these new service offerings, whilst managing potential externalities. The trend, though, is allowing greater market freedom to combine the best elements of competitive tendering and economic deregulation. This next generation service delivery model bodes well with the shift in public transport contracts from their present output-based form (delivering kilometres on defined modes) to outcome-based models which seek to deliver accessibility using any mode—thereby becoming truly mode-agnostic (Wong and Hensher 2018). We return to this matter in Section 5.4, discussing shared mobility contracts.

Hensher (2017) argues that MaaS provides the opportunity to better match customer needs more closely to service supply opportunities. It does this in the short term largely by filling gaps in service offerings between public transport (e.g., route buses) and taxi services (a gap we call intermediate modes), using the digital app capability of smartphones (Cervero et al. 2017). The car tends to play a key role in these extended offerings, whether in sole use mode or shared use. In this sense, MaaS, in integrating intermediate modes as part of the broader transport offering, can be seen as bringing together what is often termed flexible transport services, such as demand responsive transport (DRT), with the MaaS value add being the offering of such travel options direct to interested users via a smartphone based digital app (Hensher 2017).

1 http://maasaustralia.com targeting the business-to-consumer interface.
2 http://skedgo.com targeting the business-to-business and business-to-government interface.

The history of customer-focussed DRT is littered with examples that turned out to be high cost ways of providing travel opportunities, particularly in low density demand settings, and this sums up the challenges facing MaaS in Australia (and elsewhere), particularly in the short term: How can a wider range of service offerings be provided to customers, that better meet their needs in a cost-efficient manner, particularly in a country where even the higher density parts of the biggest cities are relatively low density in international terms? Hensher (2017), for example, cites the 'mobility on demand' example of Kutsplus in central Helsinki, where the subsidy per trip was around 20 Euros, never likely to be a viable long term solution. This poses the question of whether MaaS will ever actually extend beyond the spatial reach of a city's train/tram networks? Will it amount to anything more than Uber-type services linking to mass transit in an enhanced first-mile/last-mile service offering? Will it replace public transport as we currently know it in low demand settings, where service economics may be more favourable to a car-based service than a linked mass transit solution, at times? Policy settings will play important roles in answering such questions.

Cost-efficient service provision in personal and shared transport is very much about getting labour costs down, since labour is typically the largest cost of providing personal transport. For those driving themselves, the labour cost is their own and is often ignored. In 'public' transport, including taxis, ride hailing, etc, the labour is the driver's remuneration and, for urban route bus service, for example, labour typically accounts for about half the cost of the service. Mulley and Daniels (2012) have shown how the frequency(ridership)/coverage trade-off in public transport service provision can be approached by loading up kms/hrs on better used trunk routes and using freed up kms/hrs to provide coverage through a more flexible system, commonly involving smaller vehicles and, sometimes, different (cheaper) drivers. There is an opportunity to outsource this service offering to cheaper independent contractors through ride-hailing and the like, though this has not been realised in any Australian implementation.[3] Such a delivery model opens up some opportunities for demand responsive MaaS type offerings to replace fixed route/frequency PT services at times of low demand. A number of trials are now in operation across Greater Sydney, though they constitute an added service on top of the present bus offering (see Section 5.4).

Longer term, driverless (autonomous) vehicles offer a real opportunity to dramatically change the economics and scalability of MaaS, by taking out the driver's cost. In the long term, therefore, we see MaaS as a major potential source of disruption to personal travel markets, particularly because of how it can potentially capitalise on the travel cost savings that may be released by AVs. In the short term, however, MaaS might be more sizzle than steak, though its steady impact on the evolving design of public transport contracts should be recognised.

Putting MaaS packages together inevitably encounters challenges of confronting modal and regulatory silos, including the data constraints that are locked in by these silos. Freeing up access to travel data is an important base level requirement for successful MaaS, as reflected in the UK Transport Systems Catapult's September 2017 initiative to establish an Intelligent Mobility Data Hub.

3 One (limited) exception is Canberra's Night Rider service (now called Late Night Rapid) which replaced demand-responsive bus services with Uber connections from a more frequent trunk bus service. Under this partnership, the ACT Government contributes $5 subsidy per trip and Uber another $5 which is provided to the customer as a $10 discount off every Uber connection to a bus trip.

2.3 Autonomous vehicles

Autonomous vehicles (AVs), which are also sometimes known as driverless or self-driving vehicles, can be classified into five levels of automation, with higher numbers meaning a higher level of vehicle independence and a correspondingly lesser onus on the human driver, with fully autonomous vehicles capable of sensing their environment and navigating on the road system without human intervention (Table 2.1). The levels are well described by Mervis (2017), in a short-hand explanation that includes a summary assessment of the prospects for each of the six autonomy levels. Advanced driver assistance systems (ADAS), as currently in use, are operative at levels One and Two, with Automated Driving Systems (ADS) operating at the higher levels. The recent Canadian Senate Standing Committee on Transport and Communications report on AVs provides a more detailed and technical description of the various levels (SSCTR 2018).

In terms of the expected benefits from AVs, **safety** has been perhaps the prime driving force behind the US interest in AVs, as discussed in Section 5, but the opportunity for more widespread availability of vehicle-based mobility **(social inclusion benefits)** and, especially operating as electric AVs, lower **environmental impacts,** are also important motivating factors, as well as the business (profit) opportunities associated with major technological change. Also, by freeing up the driver from driving, AVs mean that **time spent in vehicle can be productive.** Alternatively, people may choose to catch up on some sleep while travelling. **Lower user costs,** and freeing up household disposable income, are also in prospect, the extent depending on whether the development pathway is individual or shared. AVs also **free up road space, by enabling vehicles to operate closer together and/or by removing/reducing the need for parking space,** freeing up opportunities for more valuable use of scarce urban space. This is a substantial set of potential benefits, explaining part of the interest and excitement around the concept of AVs.

Potential downsides of AVs include **accelerated urban sprawl** and **increased urban congestion,** as discussed in Section 5. **Cyber security** and **privacy issues** are also potential concerns, beyond the scope of the present Paper.

Timing of the widespread implementation of AVs is an area of considerable uncertainty. RethinkX (2017) suggests a very aggressive development pathway, as illustrated in the quotation at the start of Section 1. In summary, RethinkX suggests that:

- approval of fully AVs will lead to a massive fight for market share between MaaS providers[4]
- costs will be driven down to gain market share
- fleets will quickly transition from human-driven Internal Combustion Engines (ICEs) to AEVs
- high utilisation rates will drive prices way down
- MaaS will be able to offer shared service at 10-25% of the cost of self-owned mobility
- this cost saving opportunity will drive rapid growth in shared MaaS.

If realised, this pathway would portend massive and dramatic consequences.

Most views are much less optimistic in terms of AV rollout. A more evolutionary perspective on penetration of AVs is provided by Litman (2018), who sees the time frame for widespread implementation being closer to three decades. Litman recognises the potential benefits of AVs but also sees challenges in implementation, from the lags built into changing the vehicle stock because of typical asset life, to higher AV costs, at least in transitioning years, and overstated expectations of AV benefits. For example, on safety, Litman notes the often cited expectation of 80-90% improvements but notes offsetting influences such as hardware and software failures, malicious hacking, increased traveler risk taking, platooning risks and increased VKT. In terms of a slower rate of market/user penetration of shared AVs, Litman points to shared AV characteristics that will lessen user appeal, these characteristics encompassing AV use in both vehicle-sharing and/or ride-sharing modes, such as hardened interiors to facilitate cleaning (e.g., vinyl seats and stainless steel surfaces), minimal accessories, security cameras, less convenience, lower status, the need to sometimes share space with strangers and reduced travel speeds when multiple drop-offs are involved (involving also reduced reliability). Some of these concerns will, no doubt, be met by market segmentation, with users paying a higher price for a higher quality shared vehicle or shared ride but this, in itself, will slow more widespread adoption.

A supportive view on slower implementation is presented by Wadud (2017), who puts together user cost profiles for AVs, to assess which user groups are most likely to be potential early adopters of full AV. These user costs include vehicle costs and time costs. The paper focuses on personal ownership, not shared use. Not surprisingly, it finds that those with the highest time values are most likely to be early adopters, these including commercial operations, which encompasses taxis and taxi-type services (e.g., Uber) and freight, together with high income households, the latter having high time values and tending (in the UK) to drive longer distances. The value of freed up driving time is highest for these groups. Extension to lower income groups is seen as a longer-term proposition, although Wadud recognises that factors like the contribution AVs can make to improve personal mobility of some older people, young and persons with a disability are likely to make some among these groups become early adopters. Wadud did not explicitly model bus operations but the significance of time costs in bus costs would make early uptake a real possibility, as reflected in the number of trials currently underway (e.g., Keolis Navya and Transdev EasyMile in Australia).

4 Increasingly the space of vehicle manufacturers as they worry who will buy their cars in the future

Table 2.1: Levels of driving automation

Level	Zero	One	Two	Three	Four	Five
What the car does	Nothing	Accelerates, brakes, or steers	Accelerates, brakes and steers	Assumes full control within narrow parameters, such as when driving on the freeway, but not during merges or exits	Everything, only under certain conditions (e.g. specific locations, speed, weather, time of day)	Everything – goes everywhere, any time, and under any conditions
What the driver does	Everything	Everything but with some assistance	Remains in control, monitors and reacts to conditions	Must be capable of regaining control within 10-15 seconds	Nothing under certain conditions, but everything at other times	Nothing – and unable to assume control
Our take on prospects	Your parents' car	Present fleet	Now in testing	Might never be deployed[5]	Where the industry wants to be	Somewhere over the rainbow

Source: Mervis (2017) table on p. 1372.

2.4 Electric vehicles

The possibility of substituting electricity for oil as a fuel source for motor vehicles is of considerable global interest, for reasons such as the opportunity for lower emissions of greenhouse gases and air pollutants (NOx, NHMC and PM), improved tank-to-wheel efficiency (about three times higher than ICEs, according to EU 2017), energy security, lower operating costs, and quieter, smoother operation. Opportunities provided by vehicle batteries, and their usage patterns, to link electric vehicles (EVs) to distributed energy systems are a further source of appeal. However, challenges such as high capital costs, range anxiety (partly linked to a shortage of charging locations), battery size, battery life and management of used batteries stand in the way of rapid implementation.

Global and European sales, however, are currently very small, with plug-in hybrid and battery EV sales, for example, representing only 1.2% of all new cars sold in the EU in 2015 (EEA 2017). The share was 22.5% in Norway (not an EU member). On a more positive note, China sold 0.5m electric vehicles in 2016, including buses and commercial vehicles, but is targeting manufacture of 7 million battery cars and hybrid vehicles by 2025 (driven much by air quality concerns). Shenzhen, with its fleet of more than 16,300 buses, is the world's largest and only all-electric bus fleet. Electric bus technologies featured prominently in Shenzhen Bus Group's[6] Bukit Merah bus contract bid in Singapore.[7] Volvo has announced that it will only launch electric and hybrid models starting from 2019. France and the UK have announced plans to ban sales of diesel and petrol cars by 2040, with local air quality again a key driver of this change but GHG emission reduction is also important. The Netherlands and Norway plan earlier phase out dates.

Australia's high GHG emissions should make penetration of EVs powered by renewable energy a high policy priority. A relatively fast move towards electric vehicles (EVs), in particular, would be of great assistance in terms of lowering emissions outcomes. CSIRO (2017) estimates that electric vehicles are already 50-70% less emissions intensive than ICEs in Australia, arguing they are essential to widespread emissions reductions from light vehicles. They find, however, that electric vehicles are not yet cost competitive. A recent meta-study of take up forecasts by Energy Networks Australia (ENA) and CSIRO (2017) found that, without significant policy interventions or sharp rises in fuel prices, electric vehicle adoption is likely to remain well below 15% in Australia by 2030. Electric vehicles are, therefore, currently not expected to provide a major contribution in reducing light vehicle emissions intensity before 2030. However, mandatory emissions intensity standards, along the lines of EU or US standards, would rapidly change this setting.

2.5 Conclusion

Autonomous vehicles (AVs) are perhaps the most discussed subject of disruptive technological change in personal mobility. Time frames for implementation are contested but there is an air of ultimate inevitability, given the potential benefits from AVs in areas such as safety and social inclusion. However, AVs could also have major deleterious effects on traffic congestion and other land use transport outcomes. Sections 5 and 6 consider these matters in more detail and discuss how to increase the prospects for beneficial outcomes. Appropriate regulation, technology and business platforms made possible by smartphone technologies are central here.

The time frame for widespread adoption of electric vehicles (EVs) seems likely to be similar to that for roll-out of autonomous vehicles (AVs). RethinkX (2017) has argued that economics will tend to bring these two disruptions together, albeit that their assessment is that this will happen much faster than other commentators tend to suggest. However, given this longer term likelihood, it is convenient in what follows to talk about autonomous electric vehicles (AEVs) for discussion about the long term (2-3 decades) in technological disruption. We adopt this approach for most of the remainder of this Paper.

5 Vehicle manufacturers are trying to avoid this release as drivers showed slower response times to hazards and displayed a tendency to overcompensate when any driving correction was required in semi-autonomous vehicles (Shen & Neyens, 2017). There are also moral hazard issues in play, as demonstrated by the recent high-profile crash of a Tesla S on Autopilot

6 A subsidiary of Hong Kong-based Transport International.

7 This tender was subsequently awarded to incumbent SBS Transit on 23 February 2018.

3. Some societal trends relevant to technological disruption in land passenger transport

3.1 Context

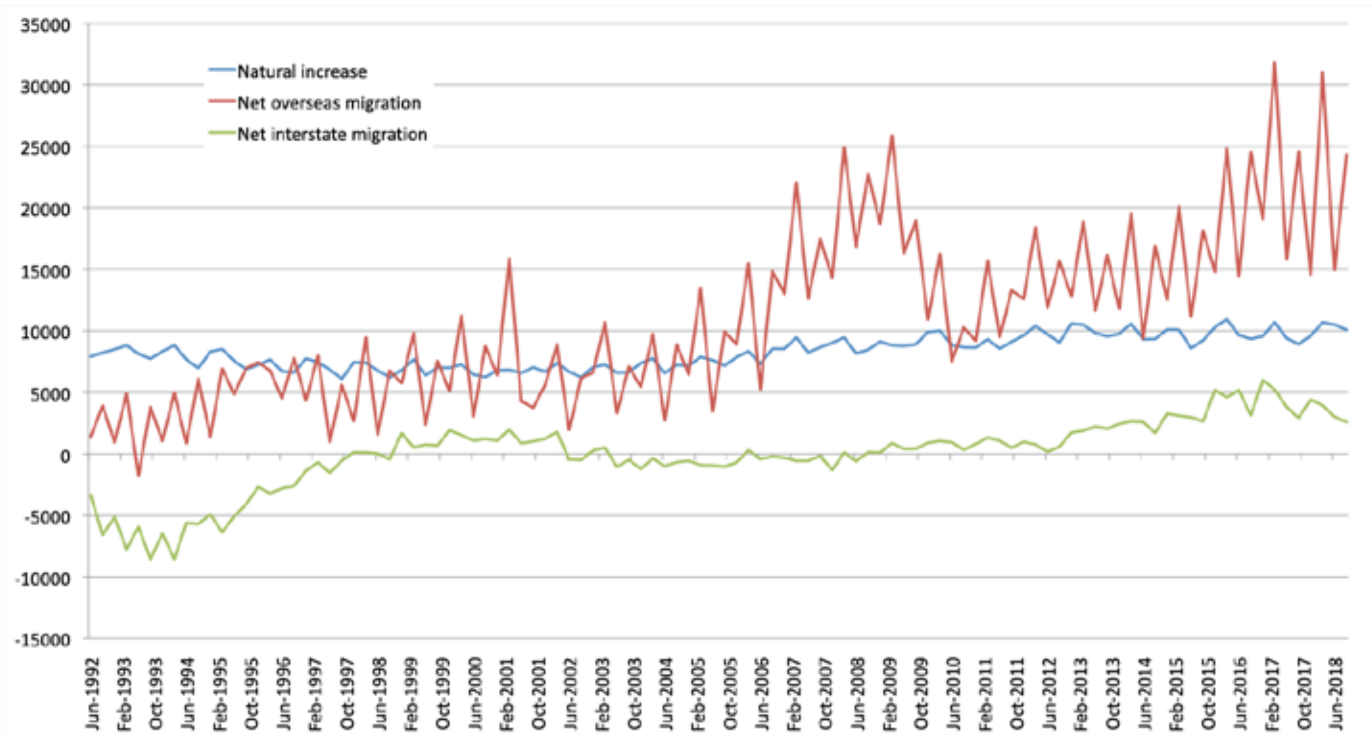
The disruptive influences on land passenger transport that are being discussed in this Paper need to be considered against the background of the major emerging socio-economic trends into which they intrude. These trends will, for example, have important influences on the likelihood and speed of adoption and the nature and scale of prospective benefits and costs of implementation in an Australian setting. The particular trends considered herein are:

- rise of knowledge economy
- personal versus sharing economy
- land use transport integration (increasing urban sprawl)
- ageing population
- need for GHG mitigation
- increasing inequality.

Readers will, no doubt, be able to add other major influences that are important contextually.

Population growth has not been specifically nominated as a separate socio-economic trend, although it is a policy variable with a major influence on current socio-economic outcomes in our cities, particularly the cities with the fastest growth rates, Figure 3.1, for example, shows Victoria's quarterly population growth over the period from June 1992 to September 2018. Rapid population growth has been mainly confined to the last decade, particularly under the influence of a high rate of overseas migration. **Overseas migration accounts for about half the total Victorian population growth over the past decade.** This rate of overseas migration is ultimately a policy variable and should be seen as such. What a continued high rate of population growth means, however, is an amplification of the significance of the socio-economic trends that are discussed in this Paper.

Figure 3.1: Victorian population growth 1992 to 2018



Source: ABS 2019, Table 2.

3.2 Rise of the knowledge economy

Economic productivity growth is closely linked to an economy's performance in high technology/knowledge-based goods and services. In the BIC's Policy Paper 5, Stanley and Brain (2015) pointed out that the total impact of Sydney's high technology industry growth between 1992 and 2012, including modest multiplier effects, is estimated to account for nearly 70 per cent of total Sydney metropolitan area growth in value added, showing the huge significance of these activities. The outcome for Melbourne was over 60 per cent of total regional growth between 1992 and 2012. These numbers underline the importance of understanding, in particular, the location determinants of high-tech/knowledge-based industries and the way planning, infrastructure, transport services and other policy levers can be used to promote their development, to promote pursuit of the economic productivity goal.

The BIC's Policy Paper 5 pointed out that productivity levels in Sydney and Melbourne generally decline with increasing distance from the centre, reflecting structural economic changes and the varying location patterns of different industry sectors. DIRD (2015) pointed to the strong growth in business services and long term decline in manufacturing, the former supporting strong central area job growth and high productivity levels, while the latter reduces employment opportunities accessible for outer urban residents. Significantly, the BIC's Policy Paper 5 highlighted the growing gap between the productivity levels in inner and outer areas of Sydney and Melbourne between 1992 and 2012, suggesting increasing inequality. The fastest rates of productivity increase have been in places where high-tech/knowledge-based economic activities are increasingly concentrating. Some parts of the outer areas in each city (led by suburban business parks, though widely skewed in terms of where these are located—e.g., Sydney's Macquarie Park[8] and Norwest Business Park located in the northern suburbs) have achieved increases in productivity levels that are in line with the median rate for the city as a whole but most have not.

Recognising the significance of the structural economic shifts taking place in our major cities, and with a desire to both improve productivity growth and ensure that the benefits of this growth are widely shared among residents, city land use transport strategies are now generally seeking to support growth in high-tech/knowledge-based economic activities, which generally requires clustering and good accessibility, while seeking opportunities to extend the accessibility of such clusters to a wider range of urban locations and residents. Melbourne and Sydney, in particular, are focussing their land use transport strategies in this direction (DELWP 2016; Greater Sydney Commission 2017). These economic/land use/transport directions form one important part of the broader strategic land use transport context against which disruptive technological changes affecting land passenger transport need to be assessed. Will these changes, such as the advent of autonomous electric vehicles, support desired economic/land use/transport policy and planning directions or might they adversely impact on outcomes in these areas? How can the prospects of beneficial impacts be enhanced?

8 Now the second largest office market in Sydney after the CBD, larger than both North Sydney and Parramatta (Wong 2017)

3.3 Have your own or be part of a sharing economy?

Recent years have seen a growing interest in what is often generically called the sharing economy. In the transport sector, car share models have been in place for many years but the scope of sharing in relation to transport is now extending well beyond car sharing.[9] More broadly, the focus in the sharing economy is essentially on consumers paying for access to (for example) services, rather than owning the means of providing them, and on making better use of underused assets, through sharing. It is important to note, however, that sharing and ownership are not necessarily mutually exclusive, as evidenced by peer-to-peer carsharing models like CarNextDoor, where vehicles are individually owned then rented out, as compared with fleet managed systems like GoGet. The ownership model for autonomous vehicles (either individually owned for sole use, individually owned then rented out, or owned by a fleet manager) will have the greatest impact on the number of vehicles in the system and the proportion of time they spend on the network (Wong et al. 2017).

Shared economy

Botsman (2015) notes that several different business/exchange models are often encompassed in the generic description, shared economy. She distinguishes between, and defines, the (Botsman 2017):

- collaborative economy: an economic system of decentralised networks and marketplaces that unlocks the value of underused assets by matching needs and haves, in ways that bypass traditional middlemen (e.g. Kickstarter)
- sharing economy: an economic system based on sharing underused assets or services, for free or for a fee, directly from individuals (e.g. Airbnb)
- collaborative consumption: the reinvention of traditional market behaviors—renting, lending, swapping, sharing, bartering, gifting—through technology, taking place in ways and on a scale not possible before the internet (e.g. Zipcar) and
- on-demand services: platforms that directly match customer needs with providers to immediately deliver goods and services (e.g. Uber).

9 US research suggests that participation in car share schemes lowers car ownership rates. For example, Martin and Shaheen (2011) reported average car ownership rates of car share scheme participants of 0.24 vehicles per household, having been 0.47/household before they joined.

New mobility services and millenials

Uber is probably the most well-known passenger transport application of new mobility services, with its smartphone based platform that enables use of underused vehicles. Cervero et al. (2018) note the rapid growth in what they call new age mobility services, ranging from ride hailing services (e.g., Uber, Lyft) to various forms of micro transit (e.g. UberPool, Lyft Line), filling out the gap between taxis and fixed route/scheduled PT, and peer-to-peer models of providing and accessing mobility (e.g., UberX). Cervero et al. note that the main reasons people use Uber and Lyft are ease of payment and ride requests via smartphone, together with shorter average wait times than taxis, reflecting the way on-demand local and integrated trunk PT services need to be thinking. In terms of social trends, they note that these qualities are particularly important for Millennials (people born between the early 1980s and early 2000s), who they describe as fuelling the meteoric rise in collaborative consumption (Cervero et al. 2017, p. 215).

Travel habits of Millennials have been a growing research focus, with a number of studies pointing out that car ownership is relatively lower among this group than in previous years. Jenkins (2017), for example, points to research by Roy Morgan Research that suggests a 5 percentage point reduction in car driving among this group between 2006 and 2016, also noting that half of the 200,000 Australians who use car sharing services are Millennials. Similarly, research by University of Michigan found that, in the US, 87 percent of 19 year-olds had a license in 1983, compared to only 69 percent in 2013 (Godfrey 2016).

Delbosc's (2017) examination of this matter, however, suggests that Millennials are deferring the time of transition to a car dependent lifestyle, rather than giving up the car. She draws parallels between this delay in driver licensing and delays in full-time work, marriage and child rearing among this generation, suggesting that the life cycle effect of auto-mobility peaks in the middle stages of the life cycle.

Economic pressures, including high youth unemployment and high housing costs, are likely to be reinforcing the delayed driver licensing phenomenon among Millennials. However, and importantly, Cervero et al. (2017) note that the residential location preferences of Millennials increasingly favour accessible, walkable mixed use neighbourhoods in traditional urban cores. These are areas where public transport service provision is usually good. Lower rates of driver licensing and car ownership, and higher use of active and public transport, including hailed app-based rides, follow this location pattern.

Shared vehicle use

The International Transport Forum (2016) has undertaken an informative analysis of what comprehensive roll-out of shared vehicle use might mean for societal outcomes. Using Lisbon as a case study, the ITF assumed replacement of all car and bus trips in that city by shared vehicle use, provided by fleets of six-seat vehicles offering on-demand door-to-door service, supported by eight-seat vehicles and 16 seat mini-buses, serving pop-up stops and providing transfer-free rides. The exercise suggested that traffic congestion would disappear, emissions would fall by one-third (more if EVs replaced ICE vehicles) and 95% of parking space would be freed up. Use of individual vehicles would increase by a factor of 10, implying shorter vehicle life, faster fleet turnover and more rapid reduction in emissions associated therewith. Mobility opportunities would be more widely available, with associated social inclusion benefits, and journey costs would be about halved. The study demonstrated the potential opportunities should widespread adoption of shared mobility be achievable. One limitation of the model, however, is the assumed homogeneity across the road network,[10] disregarding the road hierarchy and need to protect places/communities where pedestrians ought to have priority over motorised modes, bringing associated noise, air and urban amenity externalities (Wong et al. 2017).

The point to take from this brief discussion is that there appears to be a significant increase taking place in preferences for accessing services and assets by means other than outright ownership. In land passenger transport, this is seeing strong growth in (for example) demand for ride hailing and shared-ride services (from a low base), with an associated opportunity to mitigate the societal costs of Australia's high rate of car dependence for passenger travel.

These societal costs include congestion, accident costs, air pollution, climate change and growing health costs. Widespread adoption of shared mobility, including by PT, thus holds the promise of considerable societal benefit.

3.4 Land use transport integration

The dominance of major transport infrastructure projects in city shaping, and in the economic, social and environmental performance of a city, is such that it is crucial for land use transport planning to start with a clear vision of the kind of city that is desired and then use transport and other measures to help deliver that result (Cervero 2014). In this regard, most Australian cities and cities in Europe and Canada that are pursuing triple bottom line sustainability goals are commonly focussing on achieving more compact urban settlement patterns. The discussion on the rise on the knowledge economy, in Section 3.2, is a powerful economic force supporting more compact cities, because of the agglomeration economies associated therewith, but the social and environmental effects of sprawl and associated car dependency also point to the need for more compact urban growth.

The focus on achieving more compact cities has often concentrated on increasing densities through high-rise development in central/inner areas, where accessibility levels are usually highest, but there is now also considerable interest in medium density development around major transit nodes and along strategic transit corridors, including in inner and middle urban areas. The BIC's Policy Paper 5 drew attention to Vancouver's success in pursuing growth in strategic transit corridors (Stanley and Brain 2015). Reviewing triple bottom line influences on land use development directions for Australian cities, that paper concluded that (Stanley and Brain 2015, p. 24):

10 Indeed, distributor roads will see traffic increase by 76 percent and local roads by 115 percent (which can be absorbed and is within their throughput capacity limits but will bring associated externalities to communities)

... the desirable strategic land use development direction for our largest cities then becomes one seeking more compact settlement patterns, anchored by:

- *the CBD and close surrounds*
- *a small number of high tech/knowledge-based clusters (which should form the basis for a polycentric city and focal points for inner/middle urban area growth)*
- *major transport corridors that link these core nodes to the centre, to each other and to outer areas*
- *a series of constituent 20 minute cities.*[11]

Sydney and Melbourne land use transport planning directions, for example, are generally in line with this orientation, reflected in Sydney's three hubs and Melbourne's National Employment and Innovation Clusters, although Sydney has opted for a 30 minute city focus, not 20 minutes.

Under the current high population growth rates, however, a disproportionate share of population growth in some cities is occurring in outer urban areas, which makes achievement of a more compact urban structure more difficult. For example, 47% of Melbourne's population growth between 2011 and 2016 occurred in six fringe LGAs: Cardinia, Casey, Hume, Melton, Whittlesea and Wyndham, reflecting (for example) the city's high population growth rate and high cost of inner and middle urban housing. In terms of the current Paper, an important test of technological disruption in land passenger transport will be whether it supports, or undermines, the shaping of more compact cities.

Strategic public transport development directions to support the compact city land use development directions indicated above include, inter alia, provision of:

- high capacity radial networks supporting the central area and surrounds, particularly because of the agglomeration economies associated therewith
- high quality networks serving the major development nodes/clusters throughout the city and along strategic transit (development) corridors, including better connections from the fast growing outer suburbs to proximate nodes/clusters and
- local service levels that support the development of 20/30 minute neighbourhoods throughout the city.

The way that technological disruptions support, or hinder, such strategic transport development directions should form an important part of the assessment of the technologies in question.

11 By public transport and active modes

3.5 Ageing population

In 2016, some 15 per cent of the Australian population (3.7/24.3 million), were aged 65 or over (AIHW 2017). By 2056, the number of older Australians is projected to increase by 5 million to 8.7 million, or 22 per cent of the total population, increasing much faster than the overall rate of population growth.[12] Within this growing older cohort, the age distribution is also projected to shift upwards. The proportion of older Australians who are aged 65-74 is projected to decline from 57 per cent in 2016 to 45% in 2046, although numbers in this age range are still projected to grow from 2.1m to 3.3m. The proportion aged 74-85, however, is projected to grow from 30 per cent to 35 per cent of the total of older Australians, increasing from 1.1m to 2.6m. Those aged 85 and over accounted for 13 per cent of older Australians in 2016 but this share is projected to grow to 19 per cent by 2046, with the numbers in this age category increasing from 0.5m in 2016 to 1.4 million.

Along with an increase in population age levels is an increase in age-related health challenges. AIHW (2017), for example, reports that one-fifth of Australians aged 65 and over experienced disability in the form of a severe or profound core activity limitation. Research by SEU (2003), Hensher (2007) and Browning (2007), for example, indicates that older age groups are more likely to encounter social exclusion because of a lack of mobility options, particularly if there is little or no car availability or if people are not able to, or choose not to, use a car.

By implication, one particular benefit opportunity from disruptive technological change in land passenger transport may be the provision of a wider range of mobility opportunities for the growing numbers of older Australians, and most particularly for older aged persons among these groups, including in regional areas.

The focus on an ageing population, and mobility-related social exclusion risks associated therewith, is often to the detriment of other groups who also face significant mobility-related exclusion risks, particularly young people. Young people can be both independent and dependent in terms of travel needs. Independence comes from being able to walk or cycle for many trips. Dependence comes from reliance on parents/others for car travel. The BIC's Policy Paper 10 (Stanley and Stanley 2018) suggests that some young people can be doubly disadvantaged, by living in non-urban locations and coming from low income households that are unable to pay for alternative transport (e.g., a second household car or taxi fare). Particular problems include access to alternative educational programs, work and entertainment. **Thus, while an ageing population trend might be apparent for Australia, this should not serve as a vacuum cleaner in terms of sucking up all the interest in terms of who might experience mobility-related risks of social exclusion, with youth (for example) a particularly neglected group in this regard, as are regional pre-school children and those who care for them (Stanley and Stanley 2018).**

12 All projections presented in this paragraph are taken from AIHW (2017), which draws mainly on ABS (2013).

3.6 Reducing greenhouse gas emissions

Australia's 2016-17 greenhouse gas emissions totalled 550 Mt CO_2-e, some 9.1% lower than 2005 emissions (DEE 2017). Australian transport sector emissions in 2016-17 were 96.5 Mt CO_2-e and have grown by over 55% since 1990, with the sector's share of Australian emissions increasing from 15% in 2002 to over 18% in 2016-17 (DEE 2017).[13] These data suggest that the transport sector is acting as a drag on national GHG emissions reduction performance.

Road transport represents 84% of transport sector GHG emissions, and must play a lead role in sector emissions reduction. Road transport GHG emissions were 72.6Mt in 2005, increasing to 78 Mt in 2014-15[14] and projected to be 85 Mt in 2020 (DoE 2015). A business-as-usual (BAU) projection of road transport emissions suggests emissions of around 93.6 Mt in 2030 (Stanley et al. 2018). DoE (2015) projects continued growth in Australian road transport GHG emissions, fuelled by growth in passenger vehicles and continuation of low oil prices, but argues that finalisation of fuel efficiency standards will likely lead to a significant downward revision in the emissions outlook for this sector (DoE 2015, p.6).

If the road transport sector was to be expected to meet the national 26-28% reduction target by 2030, as per the Paris commitment, then emissions would need to fall to about 52-54 Mt CO_2-e by 2030, a reduction of about 20 Mt against 2005 emissions levels but about 40Mt against 2030 BAU projections. No targets have been adopted in terms of Australian vehicular GHG emission standards but Stanley et al. (2018) show that implementation of mandatory emission standards for CO_2, in line with European or US standards, which might be met by a rapid deployment of hybrid propulsion and electric vehicles, is only likely to deliver about three quarters of the 40 Mt reduction. Nevertheless, this is important progress and, as part of an implementation package, governmental incentives should be available for bus fleet replacement by lower emission vehicles, given the increased focus that is needed on PT improvements in middle and outer urban areas, where bus is the primary mode of PT delivery, to achieve more compact cities. By implication, however, behaviour change measures that reduce the rate of growth of motor vehicle use will also be needed if road transport is to carry its share of responsibility for lowering GHG emissions. Alternatively, tougher emissions standards will be needed, or a bit of each, assuming that the (modest) 26-28% reduction target is retained. Any roll out of AVs that increased the growth rate in vehicle kilometres of road travel could have an adverse impact on Australia meeting its international obligations, unless offsetting steps are taken to mitigate emissions growth.

3.7 Increasing inequality

Analysts have drawn attention to the problem of widening disparities in income levels within some countries. Wilkinson and Pickett (2009) for example, point out how the income gap between the richest and poorest 10 per cent in both the US and UK widened by about 40 per cent between the mid-70s and mid-90s. Nobel laureate Stiglitz (2012) argues that:

> *The simple story of America is this: the rich are getting richer, the richest of the rich are getting still richer, the poor are becoming poorer and more numerous, and the middle class is being hollowed out. The incomes of the middle class are stagnating or falling, and the difference between them and the truly rich is increasing* (Stiglitz 2012, p. 7).

Picketty (2014) shows that the top decile's share in US national income increased by over ten percentage points between the late 70s and early this century. Wilkinson and Pickett (2009) go on to suggest that reducing inequality tends to produce improved outcomes across a range of indicators, such as levels of trust, life expectancy, obesity, math and literacy scores and homicide rates. OECD (2014) suggests that rising inequality in the OECD over 25 years resulted in a cumulative loss of GDP at the end of the period of 8.5 per cent.

Using Gini co-efficient data, Nolan et al. (2017) report that, while global inequality had decreased, income inequality is high and has been rising sharply among rich (OECD) countries in recent decades. They argue that recent generations are no longer on track to be richer than their parents. Nolan et al. show an increasing Gini co-efficient (increasing income inequality) for Australia, as does OECD (2017), which shows top income groups benefitted most from the 2003/04 to 2013/14 boom. Whiteford (2017) suggests a slight drop in inequality occurred 2013-14 to 2015-16, the richest 20% of households seeing their real incomes decline slightly, but that inequality remained higher than at any point before 2007-08.

Nolan et al. also point out that there has also been a pronounced increase in wealth inequality since 1980 in a number of countries, including Australia. They show that increased inequality can lead to erosion of social cohesion and trust, with confidence in national governments declining. Importantly, they stress that inequality is not exogenous: for example, they suggest that technological change (and globalization) may increase inequality but public policy can respond. For example, taxes and social expenditures can be used to reduce income inequality.

13 Note that these numbers do not include electric rail emissions, indirect emissions, or emissions from international shipping and aviation.

14 About three quarters from cars and light commercial vehicles.

With substantial proportions of national populations now living in cities, elements of the inequality challenge as summarised can be seen at city level. The BIC's Policy Paper 5 (Stanley and Brain 2015) showed, for example how productivity levels across Sydney and Melbourne decline with increasing distance from the CBD and how the gap between productivity levels in inner and outer areas widened over the two decades from 1992.

Lower public transport service levels in outer areas, and lags in provision of infrastructure and services in outer growth suburbs, compound these inequality problems, particularly in cities where population growth is surging. The BIC's Policy Paper 5 argued that infrastructure investment in public transport, supported by radial and circumferential PT service improvements, can be used to both promote productivity growth and reduce inequalities. It showed that, with well-targeted investments, the social (distributional) outcome goal can be pursued at the same time as the economic (productivity) goal. Arguments for decent local public transport service levels in outer suburbs are also supportive of reducing inequality and stronger communities, in line with the idea of building 20 minute neighbourhoods, as noted in Section 3.4 (Stanley et al. 2017).

The urgency of such PT infrastructure and service improvements is compounded by the current high rate of population growth in many outer suburban areas, which means these PT improvements should be high on government priority lists. Governmental responses to these land use transport integration challenges, to date, have tended to rely on investment in heavy rail, rather than more balanced PT investment and service development packages.

3.8 Conclusion

Technological disruption in land passenger transport does not occur in a vacuum. A range of major economic, social and environmental trends will influence the extent to which major disruptions, such as autonomous vehicles, effect societal outcomes, whether those effects are positive or negative and the timing of effects. Potential impacts will be bidirectional, in terms of policy directions that are likely to deliver the best triple bottom line outcomes, as illustrated in the brief discussion on land use transport strategic directions for more compact urban form. AVs, for example, might hold promise of substantial improvement in mobility opportunities for some older people and youth. However, unless they are substantially fuelled by renewable power sources and managed to mitigate risks of greatly increased usage, with associated risks of increased congestion and extended urban sprawl, they cannot be assumed to be a universal force for good.

4. Assessing improvements in societal welfare affected by technological disruption

4.1 Common goals for cities and regions

In line with a triple bottom line sustainability focus, the various Policy Papers prepared by the Bus Industry Confederation (BIC) have generally started from the value position that a city, or other region, whose land use and transport systems, and the technologies on which they depend, support the following outcomes ('goals') is likely to become more sustainable over time.

The goals of land use and transport systems

1. **Increases economic productivity** (which includes managing congestion). Increased Gross Domestic Product per capita is the usual indicator, albeit an imperfect indicator of human needs and their satisfaction.

2. **Environmental improvement and reducing ecological footprint** – in terms of the concept of passing on a stock of natural assets that will assist future generations to meet their own needs, however conceived at the time.

3. **Social inclusion and reduction of inequality** – this is about ensuring that all people have the opportunity to live a good life.

4. **Improves health and road safety outcomes** – an essential part of living a good life.

5. **Promotes intergenerational equity** – this goal is likely to be achieved if the preceding goals are met.

6. **Engages its communities widely** in development and delivery of land use transport plans and policies. Seen as an essential ingredient in social sustainability and a matter of rights.

7. **Pursues integrated land use transport plans/policies** in the widest sense (e.g., across sectors, levels of government, modes, etc). This is primarily about the means of pursuing goals 1 to 5. It is included as a sustainability dimension in its own right because it is so fundamental to achievement.

Items 1 to 5 in this list relate to *outcome goals*, while 6 and 7 relate to complementary *process goals* for sustainability, which talk about how outcomes should be pursued. The priority attached to particular goals may vary between different cities and regions but the commonality of the goal listings is striking. These goal listings can be taken as indicators for whether the wellbeing of society is likely to be improved or reduced by particular actions. If a particular action is expected to produce positive outcomes against some goal areas but negative outcomes on others, as is common, then weights need to be attached to particular impacts/goal areas to form a view on the overall merit of the action in question. Tools like cost benefit analysis can assist in this process. The goal listing is taken as a starting point for assessing future transport technological disruptions in the present Paper.

4.2 Performance indicators

The goals set out in Section 4.1 are high level pointers against which technological changes and policy responses thereto can be assessed. Being generic, they require more detailed elaboration if progress towards achievement is to be judged. Key Performance Indicators can be used to show relative goal achievement on key dimensions. A set of such indicators is set out in Table 4.1, to help assess disruptive technological changes in land passenger transport, drawing on the Commonwealth's recent *National Cities Performance Framework Report* (2017) and Stanley et al. (2017).

The first set of criteria in Table 4.1 relate to user benefits, the scale of which depends on the extent of uptake of the new technologies, which itself depends in significant part on the service quality of the relevant offerings. If taken to a full cost-benefit analysis, then consumers' surplus type measures would be applied to these user benefits (and costs). The blocks of economic, environmental, social and cross-cutting criteria are essentially about *externalities,* or factors associated therewith. These *externalities* relate to the impacts of the technology, and its use, on third parties and/or on the environment, matters that are not usually taken into account by users in making their travel choices and not fully reflected in market prices. The final group of criteria are about governance, relating to the how of implementation.

In similar vein to these evaluation criteria (KPIs), Robin Chase, Zipcar Co-founder, and a group of leading city and transport organisations[15] have recently produced a set of Shared Mobility Principles for Liveable Cities (Chase 2017). These principles are very much in line with the KPIs set out in Table 4.1, as applied to delivery of shared mobility.

Companies such as BlaBlaCar, Citymapper, Didi, Keolis, LimeBike, Mobike, Motivate, Ofa, Ola, Scoot Networks, Transit, Uber, Via and Zipcar have signed up to these principles, demonstrating wide support among a significant number of stakeholders. The discussion in Sections 5 and 6 in this Paper draws on these principles, which provide a reinforcing sense of direction as to what constitutes a desirable outcome to some of the KPIs set out in Table 4.1.

The KPIs and principles outlined provide a structured framework within which disruptive land transport technologies can be assessed and managed, to deliver improvements in societal wellbeing.

Section 4.3 Conclusion

Disruptive land transport and technologies should be assessed and managed in the same way that the existing land transport framework is benchmarked and as the BIC has identified in a number of its policy papers to ensure that core societal benefits and government policy objectives are delivered.

15 These are identified on the website www.sharedmobilityprinciples.org

Table 4.1: KPIs for assessing technological disruption in land passenger transport

Societal impact criteria	Indicator
USER BENEFITS	
Trips	Number of trips
Travel distance	Kilometres travelled
EXTERNALITIES	
Economic KPIs	
Productivity/output	Gross Domestic (Regional) Product per hour worked; GRP
Congestion	Deadweight congestion costs
Employment	Jobs
Government spending/borrowing requirements	Public Sector Borrowing Requirement
Environmental KPIs	
GHG emissions	CO_2e emissions
Air pollution	PM and NOx emissions
Social KPIs	
Safety	Fatalities, personal injuries, property damage
Health	Obesity, overweight
Social inclusion	Access by target 'at-risk' groups
Cross-cutting and/or intermediate impacts KPIs	
Freeing up space for place making	Hectares
Urban sprawl	Hectares and net infrastructure costs
VKT	Vehicle kilometres by motorized vehicles
Impact on transit	VKT by transit
PROCEDURAL CRITERIA	
Governance KPIs	
Integrated planning/policy	Formal and informal mechanisms in place
Community engagement	Formal and informal mechanisms in place

Source: Based on Stanley et al. (2017) and Commonwealth of Australia (2017).

10 Shared Mobility Principles for Liveable Cities (Chase 2017)

1. We plan our cities and their mobility together.
2. We prioritise people over vehicles.
3. We support the shared and efficient use of vehicles, lanes, curbs and land.
4. We engage with stakeholders.
5. We promote equity.
6. We lead the transition towards a zero-emission future and renewable energy.
7. We support fair user fees across all modes.
8. We aim for public benefits via open data.
9. We work towards integration and seamless connectivity.
10. We support that autonomous vehicles (AVs) in dense urban areas should be operated only in shared fleets.

5. Optimistic vs Pessimistic scenarios for future mobility

5.1 Two future scenarios and their potential effects

Given the uncertainties involved in predicting the way digital disruption will impact future personal travel choices, and matters related thereto, scenarios can be a helpful way to think through what the future might look like, as an aid to shaping policy responses to increase the likelihood of better societal outcomes, in terms of the societal goals elaborated in Section 4. A number of papers exploring technological disruption in land passenger transport topics have taken this approach.

McKinsey & Bloomberg NEF (2016) develop three scenarios, each linked to a specific type of city environment, which they label 'clean and shared', 'private autonomy' and 'seamless mobility'. The 'clean and shared' scenario is least relevant to Australia, since it focuses on developing, dense metropolitan areas such as Istanbul, Delhi and Mumbai. Cervero et al. (2017) use 'optimistic' and 'pessimistic' scenarios, Isaac (2016) talks about a 'driverless nightmare' scenario and a 'driverless utopia' scenario, while Susan Shaheen, co-director of the University of California Berkeley Transportation Sustainability Research Centre (quoted in Mervis 2017), talks about 'utopian' and 'dystopian' scenarios.

While scenarios often discuss the impacts of pathways on introducing technological change, they tend to be more interested in end-points and, therefore, in the current context, tend to assume widespread implementation of AEVs. In that event, the separation of scenarios for exploring the possible future impacts of AEVs (including MaaS-type approaches to service provision) depends essentially on assumptions about the penetration of **shared mobility** (vehicle sharing and ride sharing—i.e., sharing across *time* and in *space*) and the consequences thereof, as compared to **personal ownership**. Optimistic scenarios are based on the assumption of a high level of penetration of shared mobility solutions and pessimistic scenarios on a low level of penetration, with personal vehicle use remaining dominant. We use optimistic and pessimistic scenarios (Section 5.2 and 5.3) and suggest the major likely consequences of each, in terms of matters likely to impact significantly on user benefits and external costs/benefits, and hence on societal goal achievement. Neither scenario in its entirety is expected to be the eventual outcome but proposing two distinctly different futures enables some key risks and opportunity areas to be identified and policy measures to be framed to increase the likelihood of better outcomes being realised. Policy matters are discussed primarily in Section 6.

Table 5.1 summarises our assessment of the broad outcomes associated with each of the two scenarios, drawing partly on McKinsey & Bloomberg NEF (2016), Isaac (2016), Cervero et al. (2017) and Litman (2018) and adding our own insights. The time frame for the table is such as permits widespread adoption of AEVs. As noted elsewhere, cyber security and privacy considerations are not included in this assessment.

The following discussion focuses on user benefits and externalities. The subsequent discussion about potential impacts on public transport, in Section 5.4, includes shorter time horizons.

5.2 An optimistic scenario

The optimistic scenario assumes that there is substantial penetration of shared mobility, in part because policy settings explicitly target this outcome, as discussed in Section 6. We first consider user benefits from AEVs and then external effects. The discussion on the optimistic scenario in this section is more detailed than that of the pessimistic scenario in Section 5.3, because many comparisons between the two scenarios are included in this section.

User impacts

In the optimistic scenario, cheap, accessible, low/zero emission driverless vehicles are widely available on-call, either for single use or shared use but shared use mode predominates (perhaps shared in peak periods and operating point-to-point off-peak), mainly because the lower marginal user costs associated therewith outweigh potential disadvantages in terms of (for example) inconvenience, as compared to private ownership. Shared mobility brokers and/or providers (MaaS) work hard at ensuring convenience and reliability are service hallmarks. In terms of user costs, RethinkX (2017) projects this shared AV cost at four to ten times cheaper per mile than buying a new car and two to four times cheaper than operating an existing vehicle. Litman is much less optimistic on cost reduction potential from shared mobility but still sees savings. Travel time reliability benefits are also likely to occur with AEVs, with significant gains at a penetration rate of 25% or more (Atkins 2016).

Availability, convenience and cost of accessing AEVs are such that people see less need to own their own vehicles. Those who continue to own their own vehicles increasingly make them available for use by others. Also, giving up a substantial element of private vehicle ownership frees up part of the household budget for other uses. Removing the need for a driver means that travel time can be used productively, if the passenger so wishes (research is taking place on ways to reduce car sickness associated with working in the vehicle), or to catch up on lost sleep. On the negative side, cheaper travel costs will encourage additional trip making, which is likely to add to congestion pressures unless shared mobility provides sufficient offset.

AEVs can provide new mobility opportunities for people who cannot, or choose not to, drive (for whatever reason). Older people, youth and people with a disability are often mentioned in this context but there is no reason why these improved mobility opportunities cannot also extend to other groups experiencing transport disadvantage, particularly in urban areas. Our research on links between mobility, trip making and risk of social exclusion has shown the high value of additional trip making by those at such risk (see, for example, Stanley et al. 2011 a, b; Stanley and Hensher 2011).

In the early years of implementation, these benefits will probably be limited to higher income households, because of higher capital costs of AEVs but, as shared mobility choices start to proliferate, the inclusion benefit opportunity will be more widely available. Greater social inclusion is also associated with flow-on external benefits, such as improved mental health, higher employment levels, lower medical costs, etc.

The cheaper cost of AEV travel, particularly by ride-sharing, and the opportunity for new vehicular trips by mobility/transport disadvantaged people will combine to mean that the number of *person trips* increases in the optimistic scenario. Given sufficient penetration of shared mobility choices, however, this higher number of person trips can be satisfied with a slower growth in *vehicle kilometres travelled,* even though autonomous shared vehicles need re-positioning movements.

Table 5.1: Scenarios for future mobility

Societal impact criteria	Optimistic/utopian future	Pessimistic/dystopian future
USER BENEFITS		
Trips (i.e. person trips)	> than in pessimistic scenario	< than in optimistic scenario
Travel distance (person kilometres)	< than in pessimistic scenario	> than in optimistic scenario
EXTERNALITIES		
Economic		
Productivity/output	Higher	Lower
Employment	?	?
Congestion	Lower	Higher
Government spending/borrowing requirements	Lower	Higher
Environmental		
GHG emissions	Lower	Probably lower but > optimistic
Air pollution	Lower	Ditto
Open space availability near housing	More	Less
Social		
Safety	Lower accident rate	Lower but > optimistic
Social inclusion	Greater inclusion	No change or worse
Cross-cutting and/or intermediate impacts		
Expanded travel choices	Yes	For some
Freeing up space for place making	Yes	Possibly but < optimistic
Urban sprawl	Less pressure	Increased pressure
VKT by private car	< than pessimistic scenario	> than optimistic scenario
PROCEDURAL CRITERIA		
Governance		
Integrated planning/policy	A requirement for delivery	Less likely
Community engagement	A requirement for delivery	Less likely

External benefits/costs

Vehicle platooning, made possible by vehicle-to-infrastructure and vehicle-to-vehicle communication, means that effective road/PT system capacity increases with widespread use of AEVs, although separate right-of-way is likely to be required to maximise this increase. Friedrich (2016), for example, has estimated the effective road capacity increase achieved by purely autonomous traffic at 40% in city traffic and 80% on highways, with other estimates even higher. For example, Bierstadt et al. (2014) suggest freeway capacity could double with 100% AVs and Fernandes and Nunes (2012) show theoretically how lane capacity could almost quadruple with optimal platooning. This, and the freeing up of parking space attributable to lower personal ownership of vehicles and a greater reliance on ride sharing, means that scarce urban space can be released for other community uses, such as local open space, in the optimistic scenario.

Taking these capacity considerations into account alongside expected slower growth in VKT, as compared to the pessimistic scenario, means that realisation of the user benefits from AEVs can be achieved with lower congestion pressures under the optimistic scenario than in the pessimistic scenario.

The main benefit of AEVs is often cited as safety, widespread use expected to deliver substantially lower accident rates. The 90% or so scale of reductions often cited (e.g. Fleetwood 2017) are questioned by Litman (2018) but significant benefits are still in prospect, depending partly on the regulatory environment that is put in place. The greater use of electric AVs, fuelled by clean energy sources, and slower growth in VKT under a high penetration rate of shared mobility, should combine to deliver lower emissions of GHGs and local pollutants, with associated health benefits.

With vehicle use in the optimistic scenario now paid for on a more direct pay-by-use basis, active transport is likely to account for a higher mode share than in the pessimistic scenario, with multiple societal benefits (e.g., improved health, lower congestion). The higher mode shares for active travel will, in turn, be supportive of more compact settlement patterns than in the pessimistic scenario. One implication is likely to be relatively higher urban productivity from clustering in the optimistic scenario. Also, the more compact urban form will mean a lower level of infrastructure spend on the urban fringe and beyond, easing government borrowing requirements.

It is important at this point to emphasise that some key external benefit issues tied up in AEV discussions, such as GHG emissions savings and lower local air pollution, are important policy matters in their own right and need to be resolved in both scenarios. Similarly, much of the social inclusion benefit of AVs (and AEVs) are likely to be available under both scenarios, because of the presence of driverless vehicles in each. Second order differences may arise, however, in terms of the scale of benefits as between the two scenarios and in the rate at which these benefits arise during the transition pathway. For example, the higher levels of VKT expected under the pessimistic scenario will mean higher GHG emissions and air pollution, to the extent that this scenario has a higher level of VKT than the optimistic scenario, albeit that GHG emissions on both should be well below business-as-usual projections.

Similarly, the optimistic scenario should be expected to deliver bigger inclusion benefits because it is expected to mean lower unit costs of travel (because of greater penetration of shared mobility) and less contrary pressures from accelerated urban sprawl, with fewer associated expected adverse impacts on PT availability (harder to ensure in lower density settings), all adding up to net relative inclusion gains for the optimistic scenario.

5.3 A pessimistic scenario

Much of the discussion in Section 5.2 applies to this section. The pessimistic scenario assumes that attachment to private vehicle ownership and use remains strong, such that vehicle sharing and ride sharing play only relatively small roles in future mobility provision. McKinsey Bloomberg NEF set up this kind of scenario as follows:

> *The attractiveness of the private vehicle. The advent of desirable and highly personalised cars – which would frequently also be electric – may maintain consumers appetite for a private vehicle. In this vision of the future, consumers are likely to value both their privacy when travelling and the independence of owning their own car. Accordingly, car sharing, ride hailing and ride sharing remain complementary options but do not replace commutes on a large scale.* (McKinsey Bloomberg NEF 2016, p. 34).

In this setting, the personal appeal of private ownership, reinforced by the perceived lower cost of AEVs and opportunity to use travel time productively lead to increased personal trips, with vehicle kilometres increasing at least as fast as personal trips but most probably much faster, as car owners avail themselves of the opportunity to call up their car when they want it (e.g., to collect them), send the vehicle to find its own parking space or to serve travel needs of family members or friends. With the added demand from those for whom AEVs provide a new travel opportunity (social inclusion benefit), growth in VKT will thus be faster in the pessimistic scenario than in the optimistic scenario, but the number of person trips may not increase as much as in the optimistic scenario. The pessimistic scenario has more trips on road but probably less across all modes. These various influences mean that traffic congestion is likely to increase relative to the optimistic scenario but also probably in absolute terms, more than offsetting the benefit affect of AEVs in terms of increasing effective road capacity. They also mean that car parking space will be required in greater quantity than in the optimistic scenario, reducing the opportunity to convert such space to other valuable community uses.

The opportunity to work-in-vehicle, or rest/sleep while travelling, instead of having to deal with the driving task, will be seen by some people as an opportunity to change place of residence, most likely to consume additional space by moving to the peri-urban area or even beyond, extending urban sprawl. This will be a compounding factor increasing VKT under the pessimistic scenario, also increasing attendant risks of greater social exclusion for those with fewer mobility choices and increased costs of infrastructure and service provision. The opportunity to live further out will be most available to those on higher incomes, the sprawl effect, however, tending to worsen public transport travel opportunities available to those on lower incomes.

Increased sprawl under the pessimistic scenario will be associated with reduced urban productivity, the BIC's

Policy Paper 5 showing how productivity levels decline with increasing distance from the CBD (Stanley and Brain 2015). Also, the infrastructure costs of accelerated urban sprawl under the pessimistic scenario mean added pressure on government borrowing requirements. **We see the consequences of greater urban sprawl as potentially the biggest single risk from widespread adoption of AEVs.** The risks from technological disruption in this regard add to challenges to sprawl already being experienced in the larger cities from a high rate of population growth, ahead of requisite infrastructure and service provision.

Employment impacts of AEVs are hard to assess as between the two scenarios. The removal of the need for a driver will clearly cause significant job loss in sectors such as freight, bus and taxi but offsets of some unknown proportion should follow from higher urban productivity associated with the optimistic scenario.

5.4 Implications for public transport

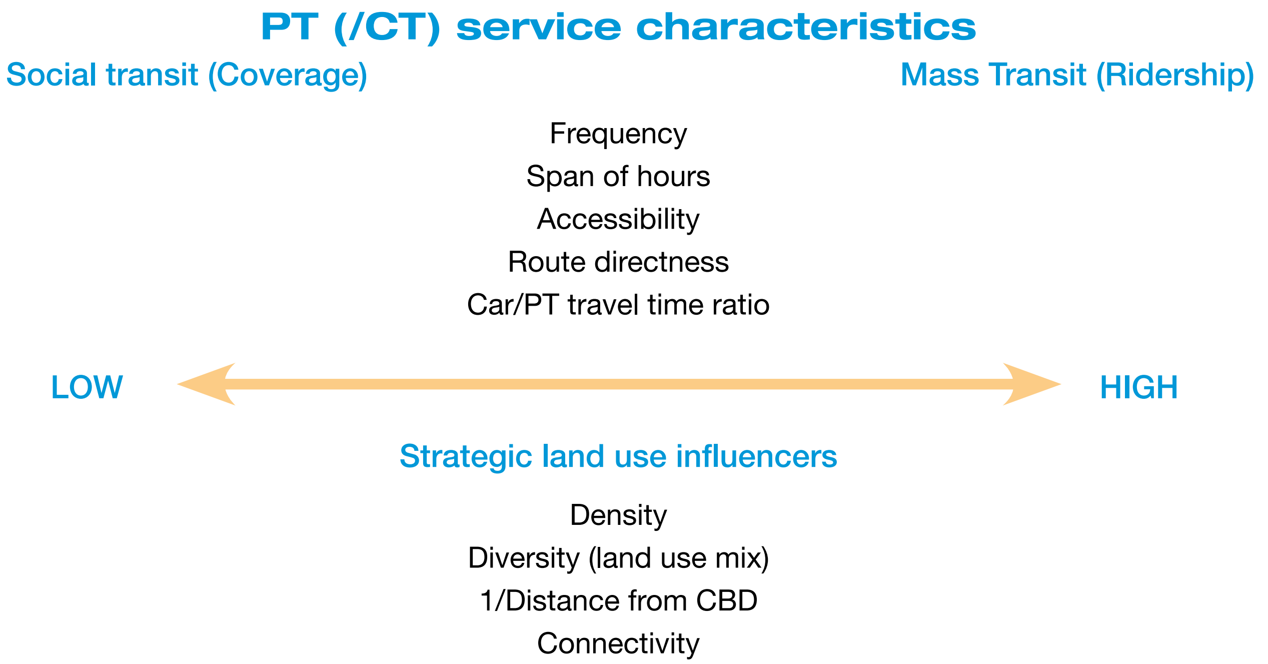
5.4.1 Markets subject to most pressure for change

Given the particular interests of the BIC and its members, we consider the way that AEVs might impact on public transport in coming years. Removing the need for a driver makes AEVs an appealing proposition for much public transport and the potential low cost of shared AEVs opens up market opportunities for such vehicles to provide services that are currently regarded as 'public transport'. For example, micro transit (6-12 passengers) could provide frequent, demand-responsive service (Litman 2018), supporting development of 20 minute neighbourhoods. However, shared mobility solutions will be somewhat harder to deliver in the low density settlement patterns that characterise Australian cities and regions than in higher density settings, because of service economics. In this section we present a brief outline of public transport service economics, since some existing PT services (i.e., shared mobility) may be at considerable risk as MaaS/AEV use grows.

In service cost terms, public transport service provision confronts a trade-off tension between pursuing patronage or ridership, which tends to produce relatively low costs per passenger kilometre and delivers economic and environmental benefits, versus service coverage for social inclusion purposes, where costs per passenger kilometre tend to be high. This market distinction is often described as being between *mass transit* services and *social transit,* or between *ridership* and *coverage*. Figure 5.1 characterises service by mass transit and social transit across a city and links this to characteristics of urban structure that have been shown to affect PT patronage and car use (Ewing and Cervero 2010).

In outer urban (and regional) areas, land use density and mix (diversity) are usually low and so is PT service connectivity but distance from a city's CBD is relatively high (shown in reciprocal form in Figure 5.1 as 1/Distance from CBD being low). PT service characteristics in this setting are typically relatively low frequency service levels, shorter span of operating hours, less direct routes and relatively poor travel time compared to car (including access/egress/wait stages). Accessibility is also usually poorer in low density areas, in both the sense that stops may be less accessible than in better served areas and in the broader sense that fewer access opportunities will be available by PT, within any given travel time. As distance from the fringe reduces (i.e., the CBD is closer), densities increase, land use diversity (mix) typically increases and PT connectivity improves, because PT services operate at higher frequency, over longer spans, with more direct routes. PT door-to-door travel time improves somewhat relative to that by car.

Figure 5.1: Aligning PT service with land use



PT operating cost per passenger and per passenger kilometer tend to be relatively lower for mass transit services, where scale economies are most likely, and higher for the social transit service, recognising that different PT modes may perform some or all of these respective services. Thus, for example, Victorian 2016-17 Budget Paper No. 3 (DTF 2016) suggests that 2015-16 Melbourne public transport costs, mainly operating, were:

- $5.28 per passenger for bus (of which perhaps one fifth is capital cost)
- $3.35/passenger for train (payments for metropolitan train services) and
- $1.06/passenger for tram (payments for tram services).

Conversely, however, capital costs for mass transit, particularly rail and tram/light rail, are high relative to social transit, for reasons such as the high cost of land acquisition and/or tunneling (purchase/construction of dedicated right-of-way), fleet costs and signaling systems. For example, Melbourne's Metro Rail Tunnel project has an estimated cost of $11 billion, none of which is reflected in the $3.35/passenger cost.

The high capital costs and associated high patronage of rail mass transit services to central cities provides them with significant natural monopoly characteristics, which suggests multiple sources of supply are unlikely.[16]

The agglomeration economies, congestion cost savings and environmental benefits (external benefits) associated with such services speak to the importance of strong governmental control over service provision, rather than leaving them to the dictates of the private marketplace, where under-provision would be expected, relative to the scale of external benefits.

> We conclude that natural monopoly characteristics and external benefits are such that, in coming years, the Australian mass (trunk) transit market should remain as public transport as we currently understand it. There is a need to include these trunk services in MaaS bundles, for which they will provide a fundamental ingredient. Also, given the important service role they will inevitably play therein, providers of mass transit could decide to take on a role as MaaS brokers.

There is interest, for instance, from Metro Trains Melbourne in *access contracts* to expand their service offering to cover the first/last mile to/from stations, through innovative ridesharing programs and partnerships with ride-hailing providers (Wong and Hensher 2018). Developments in other markets, however, are less encouraging, as independent MaaS operators attempt to displace public transport with intermediate modes where the profit margin is higher and to sell more expensive mobility packages.

Social transit services are much less likely to generate agglomeration economies, congestion savings or environmental benefits but can deliver significant social inclusion benefits, which our research shows has a high monetary value.

Importantly, these services can be provided by smaller units than mass transit services, which makes them more open to competition from a new provider than is the case with mass transit. **It is these local social transit services that we see are most likely to face competition from expanded personal travel opportunities offered through MaaS-based shared mobility services.** Significantly, the valuable social inclusion benefits from social (local) transit are also likely to be available from an alternative form of local service provision, at least to some extent; they are not unique to local bus services, for example. It thus comes down to who can provide an adequate level of social (local) transit-like service most effectively, efficiently and sustainably.

This discussion can be summarised graphically, as in Figures 5.2(a) to (d). In simple terms, public transport can be categorised as either mass transit (trunk services) or local (social) transit. Some of the latter services are well patronised and others are less so, as in Figure 5.2(a). There is a general tendency at present for state governments to shift resources into expanding mass transit and well patronised local services, as in Figure 5.2(b), sometimes to the detriment of service levels on less well patronised social (local) transit service. Roll out of MaaS and AEVs can be expected to put increased pressure on the better patronised local transit services, where demand is strongest, probably replacing them with shared car/small bus-based services, particularly when these become driverless and lower cost (Figure 5.2(c)). This development direction reflects a blurring of the boundaries between PT as we have known it and private transport. Local transit services that have low patronage levels are at risk of losing all or most service in this context, particularly if governments rely on the market to provide most local PT-like services, expecting this to be at low cost (through MaaS with AEVs).

> We see this as a major risk exposure in terms of social exclusion: governments seeing MaaS/AEVs as almost the ultimate deregulation, with the market providing services to all at a very low cost. This greatly overestimates, we believe, what might be possible in terms of commercially-based service offerings in low volume markets. Risks are less if service delivery agreements are used to assure service continuity in some form. Fare discounts may remain for some types of passengers but there may be fewer services available locally, if patronage levels are poor, on which to take advantage of these discounts.

One likely PT operator response to this evolving setting is suggested in Figure 5.2(d), where the mass transit operator seeks to extend their influence across the full service spectrum, absorbing the MaaS broking role within their business model. Within this model, the PT operator may seek to directly provide a wider range of services or else sub-contract others to provide some elements. In any event, low patronage local services will remain at greatest risk.

16 Although vertical separation of track and services can be used to reduce the degree of natural monopoly.

Figure 5.2(a): Public transport route service markets – a simple characterization.

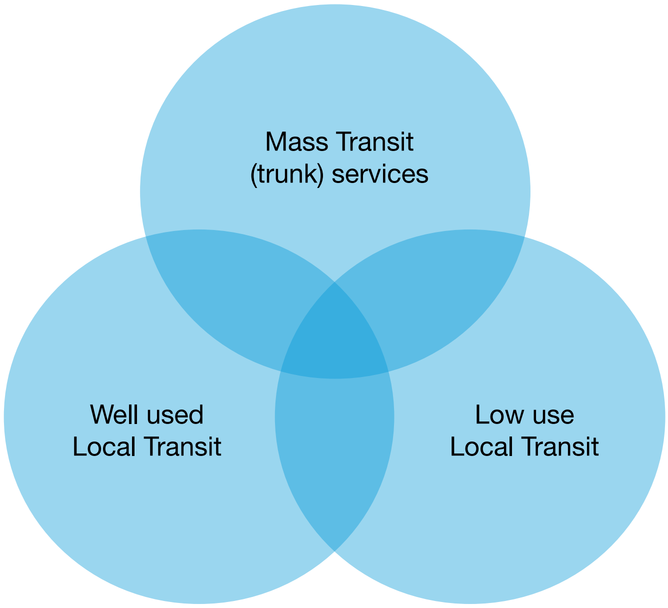


Figure 5.2(b): Current tendency for PT service development

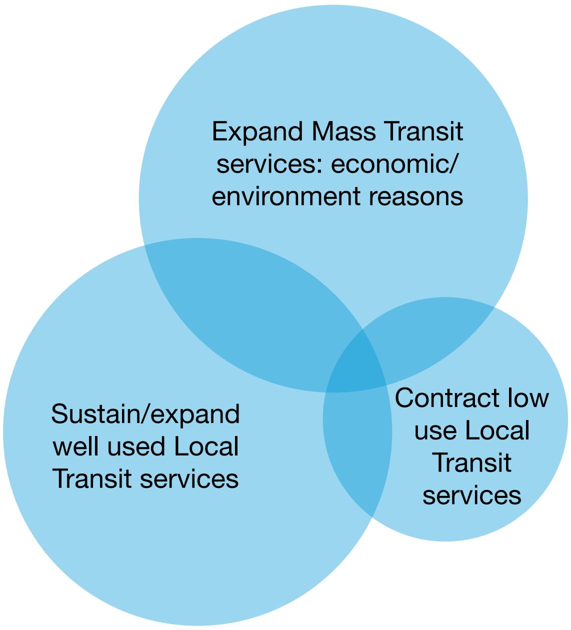


Figure 5.2(c): Possible consequence of shared mobility growth, by about 2030

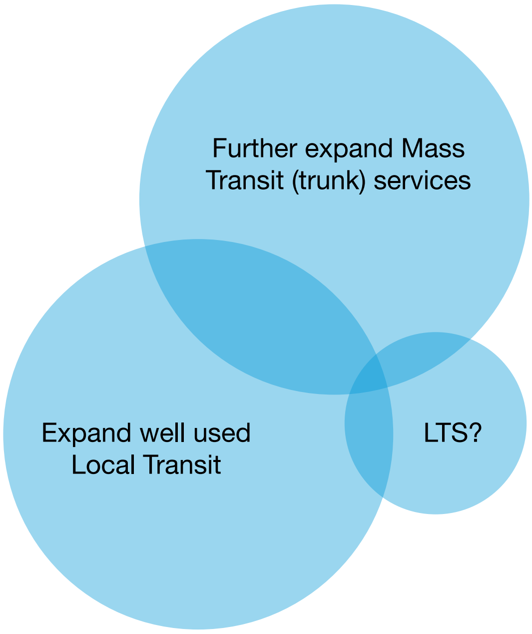
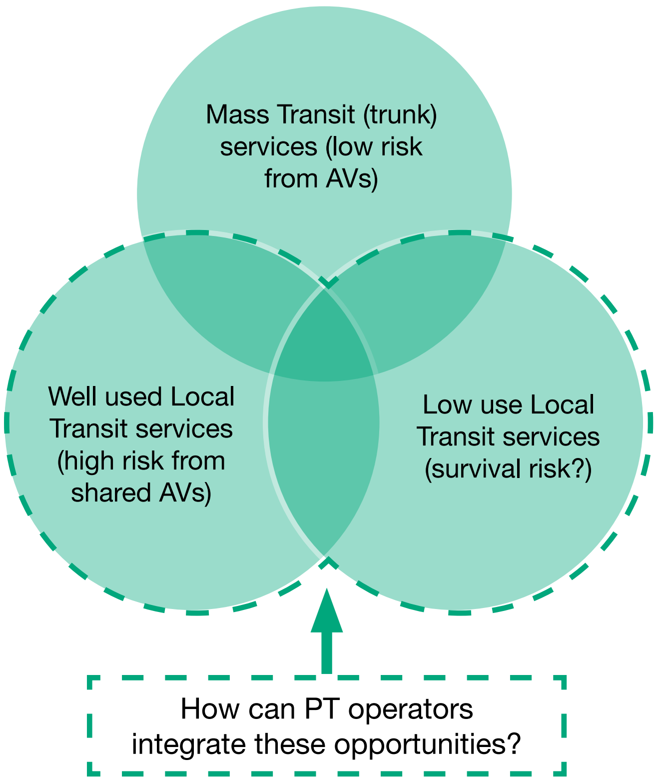


Figure 5.2(d): Likely PT operator response



Some operator cross-subsidy of service costs on lowly patronised social transit routes, from their revenue streams on more commercially viable services, might take place, especially if operators seek to grow market share with a view to the long term. Nonetheless, if service provision at the low patronage local end is left entirely to the private market place, then exclusion risks will increase, particularly in fringe urban/regional areas and in rural/regional settings, where demand densities are least supportive of commercially viable offerings for shared mobility. Alternatively, service delivery agreements could be used, between authorities, trunk operators and local operators (including MaaS providers and/or particular shared mobility providers), to ensure a range of service offerings continues, as discussed in Section 5.4.3.

The extent to which existing and developing local PT services are under threat from new (MaaS-based) service offerings will depend in part on the way future urban development takes place. Australian capital city integrated land use transport strategies are increasingly being geared to deliver more compact cities, involving increased densities in outer growth areas. For example, the Ministerial Advisory Committee for *PlanMelbourne* 2017-2050, on which one of the present authors was a member, proposed a minimum 25 dwellings per hectare for Melbourne's growth areas and Toronto is now working to new Greenfield densities of around this level. If these densities can be achieved, the boundaries between social transit and mass transit will be narrowed, tending to sustain a higher level of mass transit in the form we currently know it than if lower densities persist but still likely to see substantial involvement of MaaS and disruption of existing PT at local service level by shared mobility services.

Whilst the suggested future of PT operators absorbing the MaaS broking role within their business model constitutes a longer term development, much innovation is already happening, with forays into intermediate modes and new models of providing local (coverage) transit. Whilst this is evident from the innovative work of multinational multimodal operators (e.g., Transdev, Keolis) in overseas markets, local Australian operators are also keenly exploring this space. In NSW, on demand services have being trialed since late 2017 in the form of government-led pilots, with various models deployed in Metropolitan Sydney, Outer Metropolitan Sydney and (from late 2018) in Rural and Regional NSW. Existing PT operators are partnering with technology providers to deliver these new innovative services (Table 5.2). **Whilst this first wave of services has been government-led, bus operators are rolling out their own on demand services independent of government as well.** There are varying reasons and levels of enthusiasm for this, with the cynical seeing it as a way to impress and keep/win future tenders, given government interest in on demand services. Indeed, on-demand public transport is being integrated as part of conventional bus service contracts, as evidenced by the recent SMBSC[17] Region 6 contract offering.

One of the key issues in any business collaboration is that of branding and customer ownership. There exists a view that transportation network companies delivering intermediate modes are keen to integrate additional modes (including public transport) as part of their existing branding, whilst bus operators are wary of losing their branding and identity in any MaaS-type service offering. This concern was raised prominently at the Thredbo 15 conference[18] in Stockholm (August 2017) by Workshop 7 participants on the 'uberisation' of public transport and MaaS (Mulley and Kronsell 2018). Research at ITLS is further investigating the conditions for stakeholder support/investment (including from both mode-specific operators and non-mobility providers) in MaaS broker businesses including how brand issues might affect bidding power (Hensher 2018).

5.4.2 Public transport service subsidies and road pricing

Discussion in Section 5.4.1 noted that fare concessions may continue under a public transport future in which MaaS, using AEVs, provides a significant share of local PT. Those fare concessions are usually provided to assist groups of people, likely to be transport disadvantaged, to have increased travel opportunities, with seniors and young people/children usually eligible, together with a range of others (e.g., health care holders, disability support pensioners). There is no reason, *a priori*, to expect that such fare concessions will be any less relevant in coming years than they are today, to help assure better mobility opportunities for potentially transport disadvantaged groups. We thus assume that fare concessions will continue. The question remains, though, what might happen to public transport service subsidies currently provided by state governments to support PT operations?

The answer to this question depends in part on future road pricing reform. Workshop participants at the Thredbo 15 Conference (Workshop 5) developed the following formula, to enable estimation of the level of cost recovery that should be sought from system users via fares (Stanley and Ljungberg 2018):

[1] Amount to be re-covered by user fares = MSC – PTEB – MSLC

where:

MSC = (Efficient) Marginal social cost of PT service

PTEB = the net external benefits of PT (system-external benefits, such as agglomeration economies, health benefits and environmental benefits, should be funded by beneficiaries if possible; system-internal benefits, particularly Mohring network scale benefits,[19] should be funded by government)

MSLC = Minimum (safety net) service level cost (which should be funded by government).

Public transport service subsidies are currently justified, in large part, because road users do not meet the societal costs attributable to their travel choices, including congestion, air pollution, GHG emissions, accident costs, etc. If road use was priced so that users were required to fully meet the marginal social costs attributable to their road use, then a large part of the system-external benefit component of PTEB,

17 Sydney Metropolitan Bus Service Contracts.

18 The International Conference Series on Competition and Ownership in Land Passenger Transport, commonly known as Thredbo (http://www.thredbo-conference-series.org)

19 The Mohring effect (Mohring 1972) is listed as a potential benefit of public transport in the Externalities: system-internal category. This benefit item essentially refers to scale or network benefits that may sometimes accrue to PT users from increased PT service levels. For example, more frequent PT services, in response to increasing demand, imply shorter waiting times, with marginal waiting costs less than average waiting costs. For example, Jansson, Holmgren and Ljungberg (2015) suggest that 30-75% of urban PT marginal costs might potentially be eligible for subsidisation in an optimal pricing model, solely because of the Mohring effect.

that essentially relates to road use being improperly priced, would drop out of the PT fare setting equation, implying higher fares. Lower service costs from shared mobility solutions may mean, however, that PT fares may not need to rise. Australian urban PT cost recovery rates around 30% are common on marginal costs and, recognising that some of the elements in equation [1] will remain under road pricing reform (PT system-internal external benefits plus social inclusion benefits), suggests the potential for fares to be at broadly similar levels to today in a system where shared mobility solutions provide much of the local transit task.[20]

Australian Governments at federal and state level have long resisted road pricing reform, in spite of numerous inquiries proposing implementation. However, the erosion of fuel tax revenues, as EVs increasingly penetrate the vehicle market and as fuel efficiencies of ICEs further improve, will force governments to confront this issue in the medium term, with mass, distance, location-based pricing probably the most efficient solution. Furthermore, we argue in Section 6 that road pricing reform is a crucial weapon in the policy armoury required to maximise the likelihood that AEVs will deliver net societal benefits, through the incentives that pricing reform will provide to solutions that involve shared mobility.

We therefore make the heroic assumption that, within a decade or so, road user charges will much more closely reflect the societal costs attributable to road use and that PT fares will need to be more cost reflective in response.

Table 5.2: Public (bus) transport operators collaborating with technology providers to deliver on demand services

Bus operator	Platform provider	On demand services
Transdev	*In-house*	Ride Plus (formerly) in Manly and Eastern Suburbs, Transdev Link in Sutherland Shire
Keolis Downer	Via (formerly Routematch)	Keoride on Northern Beaches and Macquarie Park, Newcastle Transport On Demand in Lake Macquarie
Transit Systems	BRIDJ (acquisition)	Wetherill Park (formerly), Eastern Suburbs, Inner West (as part of SMBSC 6)
Premier Motor Service	TaxiCaller	Premier Illawarra On Demand (PODPI)
Interline Bus Services	Thoreb Australia	Interline Connect in Edmondson Park
ComfortDelGro Australia (operating as Hillsbus)	*In-house*	OurBus in Carlingford (formerly)
	Ministry of Movement (SWAT)	MetroConnect in Norwest
Community Transport Central Coast	Liftango	CoastConnect on Central Coast
Buslines	SmartMove (by Ebor Computing)	B-ConX in Northern Rivers

20 In support of this proposition, Thredbo 15 Workshop 5 participants concluded that, taking account of the potential scale of externalities: system-internal benefits, from the Mohring effect, and the value of (user) social inclusion benefits, cost recovery rates from fares for urban PT of well under 50% should commonly be expected, with rural fare cost-recovery rates lower than urban.

5.4.3 Minimum mobility service levels and shared mobility contracts

Considering equation [1], in a future road pricing setting where user charges fully reflect the social costs associated with road use, there remains a long-term argument to support PT and PT-like services because of (1) the continuing wider economic benefits (e.g., agglomeration economies) that depend on trunk PT services, (2) network economies and (3) social inclusion benefits. In the case of (2), **Mohring network external benefits,** subsidisation of trunk services will be the main policy direction and subsidy arrangements should be reflected in mass transit service contracts. For (3), **social inclusion benefits,** the focus for incidence is mainly on local transit services, including those lowly patronised services that will be at greatest risk under a future with MaaS shared mobility services playing a much larger role. Should operators (who could be new local shared mobility providers rather than existing PT providers) be supported to continue to provide some services that cater for this market in particular service areas, with service rights the subject of a competitive tendering process or negotiated performance-based contracts, as we have argued should continue in the mass transit market? Alternatively, should social inclusion support be provided to (particular) users through user-side subsidies, who are then left to choose how to use that support, along the lines of the National Disability Insurance Scheme model?

If social inclusion is seen as a societal priority, then some base level of shared mobility service to support or underwrite this outcome is warranted. We see no other way of assuring minimum local mobility opportunities are available to 'at risk' people. By implication, local *shared mobility contracts* should be developed to support provision of base social transit service levels, which would be expected to vary by demographic/land use setting. For example, expectations should realistically be for a lesser service level in a rural area than in a town. Requisite minimum service levels need to be set out in the contracts and might be expressed, for example, in terms of

- seat kilometres to be supplied per time period/ spatial setting, where time periods and spatial settings are specified, or
- the maximum wait time for a demand-responsive service, within particular locations and time periods.

Any such clauses would require mechanisms to be in place (e.g., bonuses, penalties), to help assure compliance. In pricing such shared mobility contract services, operators would be expected to take account of opportunities for cross-subsidisation from more commercially viable services, to increase their chances of placing a successful bid.

In the interests of more efficient, integrated service delivery at minimum call on the public purse, shared mobility service contracts should be as broad as possible, generally seeking to encompass route type PT services, school services and community transport service offerings. Depending on the legal context in a particular jurisdiction, shared mobility contracts would be open to bidding by mass transit operators, local transit operators and other shared mobility providers, including MaaS brokers if they so wished. They would be area-based contracts, to provide sufficient scale to achieve some service economies, with population catchments being the basis for area definition where they exist (e.g., in regional and rural areas).

Fare concession reimbursements to particular categories of user would continue to be relevant to such services (and others), preferably funded from a welfare budget!

An alternative way to approach social inclusion benefits is to pay the equivalent of a service subsidy to particular categories of at-risk users, probably subsuming existing fare concessions, and enable recipients to use the money thus allocated to purchase shared mobility services on the market. This would require identification of specific categories of eligible customers, for whom the support would be available, and a means of identifying these users when they use a shared mobility service. The latter would be easy to achieve through an app-based approach, provided eligible users all had access to such technology (most, but not all, will). Shared mobility providers would then claim on the state government for services provided, as measured through the app-based system.

However, identification of people at risk of mobility-related social exclusion is no easy task. At-risk groups can be readily listed, such as youth, older people, people with a disability, recent arrivals, etc., but risks of mobility-related social exclusion do not apply to all members of such groups. Household income is not always a useful indicator, since young people from high-income households can be transport disadvantaged. Also, making service subsidy funds available only to particular identified categories of users creates a risk of service not being available to some people who do not fit neatly into the defined categories but are, nonetheless, at real risk of mobility-related social exclusion. Similarly, some people who are currently eligible for fare concessions have high incomes and are probably not at much risk of mobility-related social exclusion. In short, clearly identifying the people likely to be at risk of mobility-related social exclusion is not easy and, furthermore, we are concerned about the possible privacy implications of an individual-based test of such risk. A further concern arises with person-centred subsidies in low density settings. In such settings, fragmented service offerings might arise, reducing the likelihood of a viable base level of service being available to people at risk of mobility-related social exclusion (a concern we have with the NDIS). Diseconomies of small scale are a real risk to base local service level provision. In our view, only area-wide shared mobility contracts for some base service level, which includes flexible demand responsive transport, can deal with these concerns.

Our preference, and that of the BIC, is thus for a subsidised minimum service level approach to shared mobility service (social transit), which supports individual capabilities and allows people to self-select on use, with existing fare concessions continuing. Importantly, **the subsidy for shared mobility service should be for service, not modes per se, and shared mobility contracts should reflect this focus.** Shared mobility contracts are most relevant in rural, regional and outer urban settings, where they could be introduced now, given sufficient institutional will to pursue more integrated service offerings.

6. Conclusion

6.1 Policy implications

Land passenger transport seems destined to confront major technological disruption over coming decades. This will include limited app-based MaaS offerings in the early years, with a much more rapid incursion of such services as AEVs become available. The timing of such availability is the subject of much debate but we are inclined to agree with Litman (2018) that two to three decades is probably the time frame for widespread availability. This means that there should be time to prepare for disruption and to apply policy settings that help to increase the probability that such disruption produces net societal benefits. Policy will need to address a wide range of matters, many of which are beyond the scope of the present Paper. We focus here on key land use transport policy settings that will encourage shared mobility to form the dominant method of new land passenger transport provision, rather than individual ownership. The scenario analysis in Section 5 suggested that this is the key to ensuring that net external benefits, rather than net external costs, flow from the disruption.

Four matters stand out as policy priorities.

1. Developing new shared mobility governance (including data availability) and strategic planning arrangements and associated service delivery contracts for provision of local public/private mobility options that support social inclusion and are integrated with mass transit offerings.
2. Managing land use to ensure that urban sprawl is tightly contained and that opportunities are used to increase the supply of open space within the built-up area, an issue highlighted in the recent report by Infrastructure Australia (2018).
3. Ensuring that transport users meet the social costs attributable to their road use, while ensuring affordable access is available to all at a reasonable level.
4. Implementing mandatory emissions standards for motor vehicle greenhouse gas emissions, to help drive technological change in a climate friendly direction, supported by behaviour change measures that reduce motor vehicle use.

Policy areas 1, 2 and 3, are all key areas of policy responsibility for states, and to a lesser extent, local government at city and regional level, areas which have formed a major focus of the BIC's Moving People policy research. Issues such as policy about emissions standards, AEV safety, vehicle design, data and communications management, privacy, cyber security, ethical and legal aspects of AEVs are also important but beyond the scope of the present Paper. These latter matters are primarily ones where the federal government must take the lead. Isaac (2016) includes some informative discussion on such matters.

6.2 Improved governance arrangements

There is no clearer statement of principles that should (1) guide strategic planning directions to be pursued through governance arrangements to manage introduction of a shared mobility future (including technological change associated with AEVs) and (2) inform processes that should characterise those strategic planning directions than the ten share mobility principles set out in Section 4.2.

10 Shared Mobility Principles for Liveable Cities (Chase 2017)

1. We plan our cities and their mobility together.
2. We prioritise people over vehicles.
3. We support the shared and efficient use of vehicles, lanes, curbs and land.
4. We engage with stakeholders.
5. We promote equity.
6. We lead the transition towards a zero-emission future and renewable energy.
7. We support fair user fees across all modes.
8. We aim for public benefits via open data.
9. We work towards integration and seamless connectivity.
10. We support that autonomous vehicles (AVs) in dense urban areas should be operated only in shared fleets.

The simplicity of these principles belies the difficulty of achievement, when judged by past and present failures in land use transport integration. For example, not all states can point to integrated long-term land use transport strategies and few, if any, have strategies to deliver low transport emission futures.

Planning land use, transport and related matters (e.g., affordable housing) in an integrated way involves aligning Strategic (policy), Tactical (system design) and Operational levels of thinking, which is no easy task. It is most likely to be achieved in urban and regional land use transport planning when there is a relationship of trust between the responsible government, industry and other stakeholders, with all having the opportunity to shape, in particular, system level responses to meeting high level societal outcome goals affected by land use transport development directions. Open consultative planning methods are fundamental (Stanley et al. 2017).

A *trusting partnership* should be grounded in (Stanley and Smith 2013):

1. **common** core objectives tied to public policy purposes (derived from Strategic level societal outcome goals)
2. **consistency** of behaviour and direction (underpinned by broad agreement about Strategic and Tactical directions)
3. **confidence** in a partner's capacity to deliver
4. respect for each other's **competencies** and,
5. demonstrated **commitment** to good faith in making and keeping arrangements and in principled behaviour.

Agreed and shared governance arrangements, including service delivery contracts, provide the glue that ties the principles together.

Public transport (shared mobility) system planning arrangements, and associated service delivery contracts, should demonstrate leadership by developing improved governance arrangements for shared mobility, reflecting both (1) the five trusting partnership qualities and (2) the ten shared mobility principles. This will inevitably require a concerted effort to achieve better horizontal and vertical integration of governance arrangements across the whole land transport domain and associated domains (e.g., affordable housing). This would constitute a major shift for the better in the way land use transport system planning is performed.

Inter-governmental processes, such as City Deals and infrastructure funding bids, provide opportunities to formally require governance arrangements that demonstrate compliance with the trusting partnership and shared mobility principles, as gateway conditions on eligibility. They should be used to drive improved planning practice along these lines, leaving scope for states and territories to define their own detailed approaches to outcome achievement.

Stanley et al. (2017) have argued that a stronger voice for the neighbourhood level is perhaps the biggest single requirement in improved governance for more integrated land use transport planning. This applies with particular force to planning for shared mobility, since it is at **neighbourhood level** that many of the largest benefit opportunities will arise, both mobility-related but also in terms of improved safety, local pollution reduction and improved place-making.

At state and territory level, early development and implementation of service-focussed shared mobility contracts would be a positive supportive step along the transition pathway to future governance models that are better suited to emerging technological opportunities, while delivering immediate benefits from realising a more integrated service delivery model. Integrated app-based booking/ticketing systems, with a range of on-demand service options, are fundamental to the prospects for MaaS and for shared mobility service in the immediate future and should be a requirement of shared mobility contracts. In support of this development direction, we propose a multi-model MaaS trial that focuses on ways to demonstrate the value to customers of an integrated app as a one-stop point for accessing all modes and also explores how shared mobility contracts might best support delivery of such new mobility opportunities.

Such a trial can be used to familiarise people with modal opportunities and sell access convenience but also to transition in due course to subscription plans that might be revealed by preferences obtained from the trial.

6.3 Containing urban sprawl

Land use development directions in Australia's major cities are increasingly pursuing more compact settlement patterns, which can involve 'hard' growth boundaries. A major risk from widespread adoption of AEVs, should they mainly proceed down a path of personal ownership mode, is that people will choose to take some of the benefits this offers in the form of consumption of greater quantities of ex-urban land, adding to sprawl, with its associated economic, social and environmental costs.

Road pricing reform, as proposed in Section 6.4 which follows, will ease these pressures, since longer trips will mean higher road use charges are in prospect, particularly if AEV roll-out leads to increased urban congestion, which is more likely under the personal ownership model. On the land use side, urban growth boundaries provide some protection here, provided they are real limits to expansion (i.e., not regularly pushed further out, or set so far out as to be ineffective). They need to be complemented by land use planning policies that keep tight control over development on the peri-urban fringe.

Higher minimum development densities on the urban fringe and beyond would also help to mitigate risks of extended urban sprawl and be supportive of development of 20 minute neighbourhoods in growth suburbs. These are an important way of encouraging delivery of more compact urban form. Toronto is now moving to minimum greenfield densities of 80 persons plus jobs per hectare, which is around 25 dwellings per hectare, in pursuit of more contained development. This is well above current outer urban densities in Australian cities but should be the kind of minimum density outcome pursued in Australian urban greenfield settings.

Fundamental to managing urban sprawl risks from AEVs is consistent pursuit of more compact settlement patterns, through strategic land use development directions along the lines outlined in Section 3.4, which forms essentially a polycentric + corridors + neighbourhoods development model.

Spatially-oriented transport directions to support this land use direction include:

- ensuring strong radial public transport to the centre, where capacity increases are required to cater for continuing strong growth (roads simply cannot carry the expected increased demands and have high external costs in/through central/inner areas)
- improving circumferential arterial roads. Road-based public transport and freight should be prioritised in use of these roads
- providing fast and frequent trunk public transport services supporting inner/middle urban nodes and development corridors, including for circumferential movement (particularly buses[21]), linked to the cluster (node)/transit corridor development focus
- better public transport connections from outer suburbs to areas of employment/activity concentration, including the small number of high tech knowledge-based clusters
- upgraded trunk arterial roads in outer growth areas (to deal with the current backlog rather than encourage further sprawl)
- increased local public transport opportunities in middle and outer neighbourhoods, to support delivery of 20 minute neighbourhoods
- improved walking and cycling opportunities throughout the whole city, with a particular focus on clusters/nodes and facilitating a city of 20-minute neighbourhoods.

Care is needed to ensure that these transit oriented development directions do not accentuate gentrification, a tendency that has been observed in a number of settings (Stanley et al. 2017).

Shared mobility use of AEVs provides an opportunity to re-engineer elements of road space, to cater for the requirements of AEVs, prioritising shared AEVs (and shared vehicles in the transition to AEVs), and to also take back some land from parking and vehicle movement, to support place making and active travel. Drop-off spaces will be needed for shared mobility in busy locations. Such initiatives are supportive of the preceding strategic development directions.

More broadly, parking policies should be changed to reduce minimum requirements in locations that are well served by transit. Following the London example of establishing and applying connected standards between densities, public transport service levels and parking requirements would be a useful initiative. Parking spaces that are provided should be priced to better reflect the costs associated with their use (integrated with road pricing reform).

6.4 Transport pricing reform

The BIC has consistently argued for road transport pricing reform that charges users for the marginal social costs of their travel choices and, when this pricing is in place, for public transport pricing (fare setting) to better reflect marginal social costs of service provision. As argued in section 5.4.2, however, some continued subsidies to public transport will remain defensible, because of the presence of wider economic benefits (e.g., agglomeration economies), network effects and social inclusion benefits from PT services.

In an Australian context, perhaps the most notable development on the road pricing front in recent years has been the support for road pricing reform expressed by the Productivity Commission (Harris 2015), the Harper Competition Policy Review (Harper et al. 2015) and Infrastructure Australia (2017) at federal level, and by Infrastructure Victoria (2016) at state level. While the Productivity Commission, Harper Competition Policy Review and Infrastructure Australia reports are all strongly supportive of road pricing reform, however, none has really confronted the prospect that *efficient road user charges* might need to increase substantially, if the societal external costs attributable to road use are to be met by users. All seem more concerned about strengthening links between road expenditure, road funding and user charging, in a way that gives road users a greater say over resource allocation decisions on roads. These are worthwhile intentions but only part of the story. Infrastructure Victoria's report more readily confronts a need to use price to influence behavior, without necessarily running for cover in terms of whether some resulting transport prices might need to increase. The Victorian Government has rejected the Infrastructure Victorian (IV) pricing recommendation but IV appears committed to the long term merits of its pricing policy direction.

Stanley and Hensher (2011) concluded that the Australian fuel excise rate at that time was 5-10c/L too low to cover the external costs of road use. Updating this work, Stanley and Hensher (2017) suggest that this gap has widened and is probably around 15-25c/L today. This underlines both the urgency of reforming the way road use is priced, in the interests of improved economic efficiency, and the need to be prepared to increase the size of charges on motorists in the process of reforming road user charging, rather than artificially constraining any such pricing reform to being revenue neutral. A significant increase is warranted, generating substantial additional revenues that can be used to improve roads, public transport and other infrastructure or services that mitigate the external costs of road use.

Fuel is not the most appropriate way to price road use. Longer term, because external costs of road use relate more closely to distance travelled than to fuel use (especially as motive technologies change), a distance-based charging mechanism should be introduced, with mass and location components to better reflect, for example, road damage and congestion impacts. The trend towards more fuel-efficient vehicles, albeit slow, accentuates pressure for such a shift in the way road use is priced, because of the revenue impact on the federal government budget.

21 Such as SmartBus in Melbourne and Metrobus in Sydney

Significantly, in terms of the current Paper, reformed road pricing would increase the cost of road use in areas where external costs are high, providing incentives for shared mobility solutions and reducing incentives for further urban sprawl, coming through increased ownership/use of AEVs. Mode shares for shared mobility options can be expected to be higher under an MSC pricing regime, which is what an efficient pricing system should achieve.

More radically, and linked to MaaS, Wong et al. (2017) proposes a framework that includes government in the broker model to allow road pricing to be incorporated as an input into the MaaS package price, to optimise/regulate for network efficiency (Hensher 2018). This would go some way towards ameliorating some of the potential road capacity issues (and other externalities, including on land use) arising out of demand for smaller and more flexibly routed services.

Regressive distributional consequences are a potential risk with road pricing reform. For example, outer urban residents, with low household incomes and poor public transport options, might face higher road use costs but with little opportunity to avoid these increases. Fortunately, shared mobility opportunities can help tackle this concern, by increasing the availability of demand responsive travel opportunities, supported by specific social inclusion subsidies that are provided through shared mobility contracts (as proposed in Section 5.4.2).

6.5 Mandatory emissions standards

The case for introducing mandatory motor vehicle emissions standards, in line with European levels, is based on Australia's high rate of GHG emissions and the large and increasing motor vehicle contributions to these emissions, as outlined in Section 3.6. By 2021, phased in from 2020, the fleet average to be achieved by all new EU cars is 95 g/km and US 2025 targets for all new light vehicles (passenger vehicles and LCVs) are 107g/km (cars 86g/km; LCVs 129g/km). CCA (2015) has proposed an Australian standard for light vehicles (new passenger cars and LCVs) of 105 g/km at 2025, showing user benefits from this standard well in excess of the costs for achievement.

Australia should move quickly to implement mandatory GHG emissions standards for motor vehicles (CO_2 emission rates), in line with European or US timelines.

Mandatory emissions standards need to be complemented by the kinds of incentives that countries which already have these emissions standards use to further incentivise increased electro-mobility, such as lower sales taxes, lower road taxes, access restrictions on dirtier vehicles, education and awareness programs and roll-out of charging infrastructure (Andwari et al. 2017). **Incentives should include measures to encourage faster take-up of electric buses in various formats (e.g. hybrid), as bus use will need to be substantially increased in middle and outer urban areas to support the compact city development model and this should be achieved in low emission format, as London is currently doing.** Longer term, mandatory emissions standards plus comprehensive marginal social cost road pricing (which benefits clean technologies) are likely to be the most effective way to 'encourage' greater penetration of EVs, from a level playing field starting point.

In terms of cutting motor vehicle GHG emissions, Stanley et al. (2018) show that mandatory emissions standards alone will not be sufficient to ensure that road transport makes a proportionate contribution to the currently committed 26-28% reduction in national GHG emissions by 2030. Behaviour change measures are also required, slowing the rate of growth in car use and increasing travel by active transport and transit (e.g., on-road priority to shared mobility vehicles, including PT and AEV when available, which would help achieve GHG reduction goals and also support wider benefits from AEVs). Road pricing reform will support such changes.

Appendix (from Ho et al. 2018)

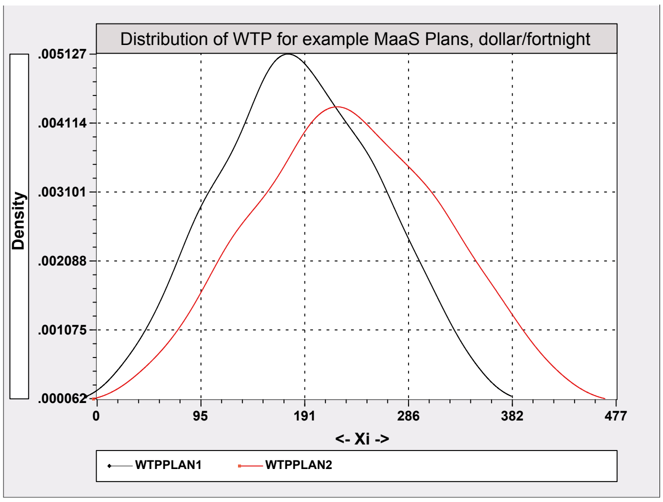
A study conducted in Sydney identified the key attributes that potential MaaS subscribers would like to see in a mobility package. Table A1 shows that on average, Sydney travellers are willing to pay $6.40 for an hour of access to car-share or about $64 per day if a full day access is priced at the rate of 10 hours – a rule employed in this experimental study and also by Sydney-based car-sharing companies such as GoGet. Options for car-sharing also include the car-sharing formats (one-way[22] or round-trip) and advance booking time which, on average, the respondents are willing to pay an extra $7.30 per fortnight for one-way car-sharing and about $1.05 less for every 15 minutes increase in advance booking time. The average willingness-to-pay (WTP) for a day of unlimited PT use to be included in a fortnight MaaS plan is $5.90 but this varies across the sample with a standard deviation of $2.40 and a maximum of $11.85 (min = 5 cent).

Table A1. Estimated respondent's WTP for different mobility entitlements of MaaS plan

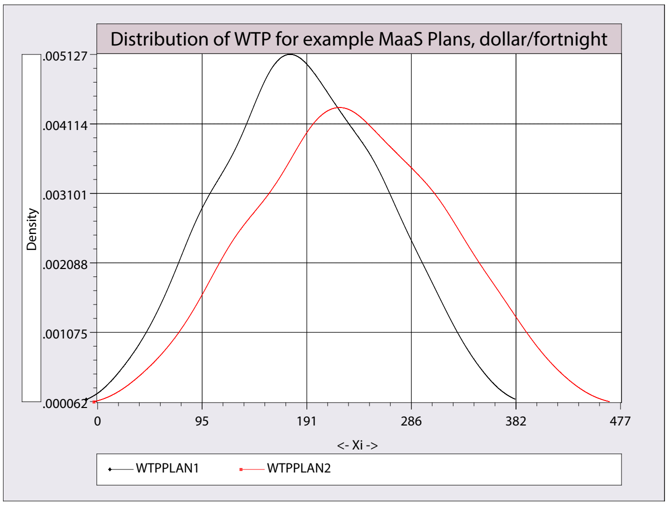
MaaS component	WTP ($/fortnight)
An hour access to car-share	$6.39
A full day access to car-share (10 hours)	$63.85
One-way car-share	$7.27
Round trip car-share	$0.00
Every 15 minutes increase in advance booking time	–$1.06
A day of unlimited PT use	$5.92
10% discount to every taxi bill	$3.68
10% discount to every ride-sharing bill	$7.18

Placing these WTPs into a context of how MaaS is likely to work in practice, Figure A1 shows the distribution of respondents' WTP for two example fortnightly MaaS Plans. Plan 1 includes two full days use of car-share (e.g., one day for each week's social outing), 10 hours of one-way car-share with a 60-min advance booking time to cover the remaining days of the fortnight (e.g., three days per week doing 30-min one-way drop-off/pick-up children at a day care centre en route to/from work and two hours weekly shopping), four days of unlimited PT use per fortnight (e.g., commuting by PT 2 days per week when children do not attend day care), and 10% discounts of every taxi and ridesharing (e.g. UberPOOL) bills. The average WTP for this example plan is $185 per fortnight. Plan 2 offers more days with unlimited PT use and more car hours on a round-trip car-sharing format with shorter notice than Plan 1. The average WTP for this plan is estimated at $231 per fortnight.

Figure A1. Distribution of WTP for example MaaS plans



Entitlement per fortnight	Plan 1	Plan 2
Car days	2	2
Car hours	10	15
Car-sharing scheme	one way	round trip
Advance notice	60 mins	30 mins
Taxi discount	10%	20%
Ridesharing discount	10%	10%
PT days	4	6
Average WTP	$185	$231



22 A proxy for autonomous taxi usage.

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Policy Paper 11

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PO Box 6171, KINGSTON ACT 2604

Tel: +61 2 6247 5990
Fax: +61 2 6273 1035

Email: enquiries@bic.asn.au
Web: www.ozebus.com.au