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Innovative responses to urban transportation: current practice in Australian cities

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Using high quality, independent evidence and through active, managed engagement, AHURI works to inform the policies and practices of governments and the housing and urban development industries, and stimulate debate in the broader Australian community.

AHURI undertakes evidence-based policy development on a range of priority policy topics that are of interest to our audience groups, including housing and labour markets, urban growth and renewal, planning and infrastructure development, housing supply and affordability, homelessness, economic productivity, and social cohesion and wellbeing.

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Acronyms and abbreviations used in this report

AHURI	Australian Housing and Urban Research Institute Limited
AT	active transport
AVs	autonomous vehicles
CAV	connected and automated vehicle
COAG	Council of Australian Governments
CRC	Collaborative Research Centre
DELWP	Department of Environment, Land, Water and Planning (Vic)
DMR	Department of Main Roads (WA)
DoT	Department of Transport (VIC)
DPLH	Department of Planning, Lands and Heritage (WA)
DTMR	Department of Transport and Main Roads (WA)
EV	electric vehicle
IA	Infrastructure Australia
ICT	information and communications technology
IV	Infrastructure Victoria
MaaS	Mobility as a Service
MLP	multi-level perspective
MRWA	Main Roads Western Australia
MTR	Mass Transit Railway (Hong Kong)
NTC	National Transport Commission
PATREC	Planning and Transport Research Centre (WA)
PnR	Park and Ride
PPP	public–private partnership
PRG	Project Reference Group
PT	public transport
TAP	Transport Academic Partnership (QLD)
TfNSW	Transport for New South Wales
TIC	Transport Infrastructure Council
TIS	technological innovation systems
TMR	Department of Transport and Main Roads (QLD)

Executive summary

Key points

- **There is extensive theorisation and knowledge of innovation systems internationally; however, the application of this knowledge to urban transport issues is less developed.**
- **Innovations are occurring in urban transport systems internationally across multiple domains, including technological advances as well as policy and institutional development.**
- **Recent analysis highlights the role of the state in fostering transport innovations and the institutional context for innovation.**
- **Passive and active responses to innovations in Australian urban transport systems are uneven and fragmented.**
- **There are many opportunities for Australia's urban transport policy and the regulatory institutional environment to better respond to innovations, including through greater coordination around agreed national goals, institutional design for innovation, and greater effort to engender cross-sectoral innovation practices.**

The study

This study responds to the brief issued by AHURI to investigate urban transport innovations in Australian cities, identify policy responses to these innovations, and chart possible policy directions arising. Scoping projects undertaken by AHURI involve 'evidence mapping' that assesses the current extent and range of current evidence, identify further research or policy development possibilities or priorities, and identify gaps in the evidence base.

This project's project scope required an investigation of how Australian urban transport programs and policies are responding to changes in transport technology, travel patterns, environmental imperatives and spatial development dynamics in order to offer guidance about future directions and options.

Four research questions guided the approach:

1. How are large-scale processes of technological, economic, social and environmental change affecting travel patterns and transport systems in Australian cities?
2. What strategic approaches to configuring infrastructure, technology, regulation and design are Australian metropolitan transport programs and policies adopting?
3. How do Australian metropolitan transport programs and policies compare to relevant international examples in terms of strategic approaches to technological, economic, social and environmental changes?
4. What forward positions should Australian metropolitan transport programs and policies consider in response to drivers of major transport system change and what further research is needed to inform this positioning?

The research was conducted through a desk-based review of the international literature on innovation, transport innovations, and on Australian state planning and transport policy (focussing on New South Wales, Victoria and Western Australia) and institutional settings. This work was conducted over 2019 and 2020.

A Project Reference Group (PRG) was established that included invited representatives from state and federal agencies. This group met twice over the course of the project to consider project directions. The PRG is not responsible for the content of this research report.

Two workshops were held with professional transport planning experts from state and local government and the private sector in Victoria and Western Australia. The purpose of the workshops was to seek responses on the framing of the project, and on the challenges and future directions for policy. These workshops provided useful feedback on the study direction. The workshop participants bear no responsibility for the content of this research report.

The study was ambitious in scope but limited by the extent of resources provided. In this respect, the study can be classed as exploratory. The conclusions of the study identify a sizeable agenda set for researchers and policy analysts seeking to further advance understandings of innovations—both at the international and national levels.

Key findings

Defining innovation

There is an extensive and growing literature on innovation that seeks to define, record and explain instances of innovation, and the underlying social dynamics that make societies, social subgroups, institutions or industry sectors innovative. Innovation debates also intersect with wider social scientific discussions, including literatures on transitions, socio-technical relationships, economic institutions and business practices.

Most transport technologies have existed in precursor form for long periods prior to their widespread application. Identifying what is new in a recent transport technology is thus not clear-cut. Critically, the value of innovation is not only about newness and novelty as such, but the creation of new value propositions for regulators, providers and travellers.

In transport, such value propositions for regulators include enhanced ability to meet overarching policy goals such as:

- reduced emissions and congestion
- increased efficiency or productivity
- greater accessibility and social equity.

For transport providers, the value proposition includes:

- greater efficiency
- greater capacity
- greater market share.

For passengers or users, the value proposition includes:

- increased usefulness
- increased accessibility
- increased inclusivity
- increased comfort
- increased convenience
- increased safety
- reduced price.

Innovation in transport technology is temporally and spatially conditioned: what is seen as innovative in one place may not be seen the same way in another place.

A first step in examining innovation responses involved the need to define and identify the key drivers of innovation in transport policy. Drivers of innovation establish background pressures on transport systems that motivate adoption of new technologies or regulatory or institutional arrangements. Defining these was critical to ensuring that:

- a comprehensive framework of innovation was established that could be used to examine international and national practices
- the study was purposively grounded in the challenges that confront Australian transport planners.

In considering a holistic view of drivers of innovation, given the above understanding, the project defined these as:

- the social, economic, environmental and institutional conditions that generate market and policy demand for innovation
- the dynamic response between this demand and suppliers.

A multiplicity of drivers of innovation were identified, including:

- technology
- social and environmental imperatives
- demand behaviour—of markets or individuals
- resource constraints—land, public and private capital
- regulatory gaps
- political imperatives.

The drivers of innovation exert influence on 'domains of innovation'. These domains are socio-technical sub-sectors of the overall transport system in which new technologies, regulations or strategic frameworks emerge and are applied. Innovation was thus framed under five 'domains of innovation':

- Transport platforms
- Influencing travel behaviour
- Urban structures
- Climate change and pricing
- Infrastructure procurement.

These five domains were considered to be the specific domains that were manifested as a consequence of the exploration of the drivers of innovation.

The analysis of international practice and of current and emerging Australian transport policy at federal and state jurisdictions was conducted using the five domains of innovation as a framing device. Here innovation can be summarised as undergoing a sequence of phases:

adoption → policy response → stabilisation

Each phase may include both private sector and public sector intervention—with public sector intervention taking place via planning, design or regulation—and these phases are noted in the review of both international and national practice.

International practice

Innovation domain: Transport service platforms

There is a great deal of diversity in transport service platforms, whether they are operating systems, large conglomerate information systems, or specific applications (such as Uber). Digital platforms have become prominent as mechanisms for coordinating service delivery, including integrated mobility services, car-sharing, ride-hailing and micro-mobility vehicles. In some jurisdictions, multimodal platforms known as 'Mobility as a Service' (MaaS) are being deployed. Further platforms are also being developed to provide autonomous vehicles, although these are not in generalised use at present.

Key issues relating to MaaS include:

- the governance of coordinating a multiplicity of stakeholders and service providers at different levels of the decision-making process
- ownership of the platform
- selection of modes to be offered in a MaaS package
- whether full coverage can be provided in ex-urban areas
- segmentation by groups and modes and issues of cross-subsidy.

Key issues for ride-hailing include the potential for quasi-monopolistic control of the platform, the avoidance of regulation and safety, and the degree to which services may be able to meet community service obligations in outer suburban and regional areas.

Key issues for car-sharing schemes typically relate to their integration within sustainable transport systems and access to public road space for parking. The geographic distribution of vehicles in car-sharing schemes indicates a dependence on relatively good public transport.

For micro-mobility, there are issues of definition, which lead to uncertainty and variation in licensing and regulation; the extent to which these modes are integrated with other modes in a MaaS platform is also of interest.

Autonomous (or driverless) vehicles (AVs) have been subject to a large degree of speculation in recent years as various automotive manufacturers compete to deliver a viable wholly autonomous vehicle to market. There is considerable uncertainty as to their technological viability, their operation within urban transport systems, their effects on travel behaviour and the institutional arrangements that should accompany their adoption. There are mixed views regarding their benefits and drawbacks for car dependency, increased distances travelled, urban expansion, reduced mass public transport use and their compatibility with complex urban environments with high levels of pedestrian activity. The timing of driverless car availability and rollout remains unclear.

Innovation domain: Influencing travel behaviour

Many innovations seek to influence travel behaviour, typically to reduce reliance on private cars. This includes explicit behavioural modification programs, such as TravelSmart, or may involve wider policy frames that reduce the convenience or raise the cost of car use relative to other modes.

The understanding of factors underpinning car dependence relative to other modes is a well-established domain. Broadly, cars are understood to offer a more convenient option that is artificially under-priced relative to other modes. However, there is a body of literature that recognises that car use is determined by institutional, environmental design, as well as individual factors.

Good quality public-transport network planning can improve the quality of service experienced by users and, in turn, support patronage growth. Although there is wide variance internationally in terms of the quality of service provided by public transport, new approaches in a specific jurisdiction may be seen as innovation even if they are already part of normal operations elsewhere.

Despite continuing telecommunications technology improvements, telecommuting had not been adopted by large numbers of employees prior to the COVID-19 pandemic. There is now substantial evidence that the COVID-19 experience resulted in large proportions of employees and employers experiencing telecommuting, with significant proportions keen to utilise it for a much greater proportion of work practices. While this 'experiment' may lead to sizeable changes in practice, the extent and durability of such shifts is difficult to predict.

Innovation domain: Urban structures

Urban structure influences urban travel patterns through the locational differentiation of land uses and transport accessibility. An urban structure that requires longer commuting distances to access employment may be less efficient than one where commuting is shorter. Various consequences arise from inefficient urban structure. The problem of labour market 'spatial mismatch' has been long understood, while issues of transport accessibility and disadvantage are also well known. Inefficient urban structures are also known to compromise urban productivity.

Efforts to manage urban structure often involve coordination of transport and land-use planning around key nodes within metropolitan areas, around which activities are focussed and to which efficient transport services are provided—such as heavy rail. These efforts may be considered innovative in relation to prevailing patterns, but they face impediments such as:

- the complications associated with ongoing car-dependent travel
- the task of coordinating and regulating land-use activities
- institutional and political support.

The expansion of metropolitan areas typically requires consideration of infrastructure servicing. In many jurisdictions, metropolitan expansion through urban development proceeds in advance of infrastructure. Basic infrastructure servicing is typically ensured but less effort is often dedicated to public transport provision. Much policy focus has been on paratransit services and like services in recent decades, and there is evidence of regular efforts to generate innovation in this area. However, a stable viable model of urban fringe and ex-urban demand-responsive transit is not yet confirmed as established, apart from very specialist tasks such as disability mobility.

Innovation domain: Climate change and pricing

Transport debates have considered who should bear the negative costs of transport infrastructure as experienced through various forms of pollution, including greenhouse gas emissions. Innovation in this domain includes:

- electric vehicle uptake
- road pricing
- improved parking-pricing regimes and regulation.

However, these areas face policy and institutional challenges that limit the pace of current change.

Across the globe, there are numerous incentives currently in place to encourage the uptake of electric vehicles. These cover purchase rebates, tax exemptions and tax credits. They also cover incentives that range from access to bus lanes to waivers on fees—parking, toll roads, user charging. The magnitude of the financial incentive is driven by the vehicle type and the size of the battery. Some countries not only incentivise the purchase of EVs, but also conversions of hybrids and conventional cars to EV, as well as fuel cell vehicles.

The major impediments to the adoption of EVs are the lifecycle cost of ownership driven largely by battery prices, and the significant degree to which charging infrastructure will be needed to overcome the relatively limited kilometre range of EVs, to enable the space to move away from what might be seen as the 'safer' options of hybrid technologies, or just cleaner fuel.

Efforts to reduce battery costs and the distribution network are ongoing globally, but in order to achieve economies of scale and render EV technology a genuine consumer choice, purchasing incentives are needed in the form of:

- exemption from taxes
- road-user charging
- capital grants.

The theoretical case for road-pricing schemes is well established but such schemes tend to face public opposition. Road pricing remains a domain that is open to innovation, not only in relation to technologies that provide for less intrusive road-use recording but also to institutional models and the potential to advocate for the wider benefits that would accrue from price signals that reduce road use at the same time as raise funds for broader environmental and transport objectives that could secure popular support for scheme introduction—if communicated effectively.

There remains potential for innovation in the domain of car parking pricing in terms of technologies, regulations and institutional models. However, this needs to be understood within the generalised framework of support for automobile travel, as parking is a consequence of wider settings, even if it is often the most prominent.

Innovation domain: Infrastructure procurement

Infrastructure procurement focusses on value capture and public-private partnerships (PPPs). If implemented carefully, value-capture models can be a robust financing alternative that could effectively support sustainable urban development and generate revenue for transport schemes. They have been successfully deployed in international jurisdictions.

Australian transport policy

This study has observed that policy discussion about transport innovation in Australia is focussed predominantly on current transport modes—rather than emerging modes—and on land-use planning to facilitate sustainable transport. This sees a continuation of practices set in the late-1990s. In each of the three states (NSW, VIC and WA) where conventional strategic urban planning and transport planning documents policy documents were analysed, the main focus is on domains of:

- **Influencing travel behaviour**—by seeking to lessen car dependency and suggest measures to improve public transport in order to address declining use by this mode
- **Urban structure**—looking to develop activity centres that are integrated with transport so that they lessen commuting.

All three states are seeking to expand their public transport networks, with an increasing focus on orbital lines and new routes serving destinations outside the CBD. There is also recognition of the importance of supporting active modes of travel via lanes and paths for cyclists and pedestrians. Other innovation domains are covered, but not consistently across states. This includes a focus on encouraging telecommuting, and on emerging transport modes: MaaS, ride-hailing, car-sharing options and AVs. NSW also includes a focus on micro-mobility.

The ability to properly implement this new urban agenda continues to be impeded by governance and regulatory barriers. These limit the ability to holistically integrate transport and land-use planning and align new land development with timely provision of infrastructure.

Constraints relate to the lack of road-user charging and patchy implementation of maximum parking ratios. The former will emerge as a critical issue as we transition to EVs and AVs. EVs will erode fuel excise revenues and without road-user charging there is likely to be less shared use of AV fleets. For the immediate future, parking caps and levies are an important demand-side response to foster development intensification of 'activity centres' while protecting their amenity. The failure to recover infrastructure costs through 'land-value capture' is another symptom of this underlying governance problem. None of the three states has a comprehensive approach to this funding mechanism, despite its endorsement by Infrastructure Australia (IA) at the federal level.

Regarding new mobility technologies and business models, the formal government and emerging policy documents show potential to 'disrupt' the private car model and reflect innovation in thinking, but the observed impacts remain muted and there is difficulty in operationalising many of the recommendations. There is a growing level of understanding regarding the potential for automated and on-demand public transport to improve accessibility to —and reduce operating costs of—transit systems. However, concrete steps to support this transition appear largely confined to NSW (of the three states that were investigated).

Forward positions

Policy development options

A key conclusion of this study is that the Australian urban transport sector lacks a coherent overarching framework for an innovation system, despite regular references to innovation in policies. The principal approach is of market-initiated innovation with regulatory anticipation and oversight at adoption. Key national agencies such as the Transport and Infrastructure Council (TIC) and the National Transport Commission (NTC) refer to innovation but their operational approach does not explicitly reflect international knowledge and practice in terms of technological innovation systems, sustainability transitions or public sector innovation practice. Infrastructure agencies such as Infrastructure Australia (IA) and Infrastructure Victoria (IV) focus on innovation through domain lenses, typically with a 'reform' perspective in terms of evolutionary policy development rather than an innovation system lens. This is not intended as a criticism of the agencies; they have been established to serve a function and as far as we have ascertained do so effectively within the parameters set. Rather, this observation points to the potential opportunity costs of further system development that could occur if a more formal and explicit framework for an Australian transport innovation system were to be adopted.

A more formal sustainability focussed innovation framework for Australian urban transport would necessarily need to reflect international knowledge and practice in innovation systems. This might be in relation to technological innovation systems or to wider sustainability transitions thinking. Agencies may wish to also consider the insights emerging from public sector innovation research, such as innovation bureaucracies.

This research has only touched on the potential for sustainability focussed innovation framing for Australian urban transport policy. More investigation is needed to better understand the potential for institutional reform driven by a sustainability focussed innovation framing. This presents a future direction for research.

A national sustainable transport innovation system would also require systematic dialogue to establish shared visions and directions for transport. This would likely require structured modes of deliberation and discussion—including identification of key societal challenges to which transport should respond through innovative change. Currently there are few vehicles for such national conversations that draw together diverse private, government and community stakeholders.

Institutions and practices

Many mechanisms have been identified that can support innovation—such as technological innovation systems—through which thick relationships are formed between private and public actors around sectoral challenges or imperatives. Innovation is often also framed from a spatial perspective via regional innovation ecosystems that activate networks of proximity between innovation actors to drive innovation potential. There is also recognition of the value of a systems- and transition-oriented perspective on innovation, so that collective societal challenges can be identified and 'mission-oriented' sustainability transitions activated that can establish pathways of succession from one technological configuration to a future more sustainable version.

Policy gaps and opportunities

This study has identified an array of innovation domains where there remain considerable knowledge gaps, whether these be in relation to:

- **technology development and adoption**—such as autonomous or electric vehicles
- **institutional questions**—such as the necessary institutional settings to establish generalised road pricing or strengthen activity centre planning in major metropolitan areas.

Each of these domains could benefit from further empirical investigation, as well as policy development attention to consider options and pathways.

Much transport innovation in the international literature is oriented to improving the sustainability of urban transport, whether through:

- reduced fossil-fuel demand
- mitigation of climate change due to vehicle emissions
- encouraging greater use of public and active transport or micro-mobilities.

Despite references to sustainability in some policy documentation, there remains a clear gap in terms of the sustainability framing in Australian urban transport. This gap could be addressed through a sustainability transitions perspective that would incorporate a combination of technological innovation and institutional reform around a national vision for sustainability. However, to initiate this direction would require a national sectoral conversation to be held which, in turn, raises questions of leadership within the sector. In the absence of innovative leadership, it is likely that business as usual will prevail.

The role of the state in urban transport innovation

An important component of the theorisation of, and institutional design for, innovation is the role of the state. This role has been present in much technological innovation but has only relatively recently been recognised as being essential to the development of technological innovation systems and to wider programs of transition towards technological and societal sustainability.

There is a critical need for further elucidation of theories of state framing and fostering of innovation in Australia —including in relation to urban transport. Such theorisation should be both:

- **conceptual**—in terms of a theoretical understanding of the state role in innovation
- **empirical**—in terms of expanding knowledge of the capacities of state actors and agencies to establish institutional, policy and regulatory arrangements that can support urban transport innovation.

Such a theorisation in the Australian context would need to be calibrated to the particular circumstances faced in Australia arising from geographic factors such as:

- the relative isolation of the country's major urban areas from other large urban areas
- the chronic relative national underspend in research and development
- the specific governmental structures and divisions of responsibility in Australia arising from the federal constitution.

The fostering of innovation within a national regulatory and policy system that is overwhelmingly focussed on competition, rather than innovation or sustainability, also deserves appraisal. There is a need to consider what the relevant federal, national (such as the National Federation Reform Council (NFRC), formerly the Council of Australian Governments (COAG) and state responsibilities are in relation to various innovation domains and the institutional frameworks necessary to advance them.

1. Introduction

- This research investigates innovations in urban transport in an international and Australian context, and seeks to identify potential policy directions for Australia's cities and policy arrangements.
- This section sets out the purpose of the research and the approach adopted.
- Section 2 reviews theories of innovation to understand current knowledge and practical applications of how to understand innovation and the institutional practices that support innovation.
- Section 3 assesses knowledge and practice in selected domains of innovation in an international context through a review of the research literature. This review demonstrates that there is substantial knowledge of technological innovations; however, knowledge of policy and regulatory innovation remains underdeveloped.
- Section 4 assesses Australian policy responses to innovation in three jurisdictions: New South Wales, Victoria and Western Australia. The policy reviews finds that there is a great degree of unevenness of policy attention to innovation both generally and in relation to specific domains.
- Section 5 considers possible directions for Australian urban transport policy in relation to innovation. The section argues that there is considerable opportunity to better orient Australia's urban transport policy institutions to an innovation perspective, and sets out a series of questions that may be posed by future research inquiry.
- Section 6 provides conclusions to the research, reiterating the opportunity that gaps in Australian urban-transport innovation thinking may offer.

1.1 Research issue

This project investigates the current state of transport policy and planning in Australian cities to identify emerging innovative practices that are responding to the various challenges of rapid population growth, expanding spatial distribution of population and land uses, and growing travel demand, within the context of fiscal constraint and the climate emergency.

Australia's major cities are among the fastest growing in the developed world. Rapid population growth, consumer demand, housing supply expansion and increased employment are contributing to new land-use configurations that are generating new spatial, temporal and modal forms of travel demand. This new travel demand has placed pressure on transport infrastructure and services which, in turn, raises public and policy concern about the plans, services and infrastructure needed to respond to these changes.

Australia's transport systems are in a period of change with new configurations of technology, infrastructure and spatial organisation emerging, while at the same time existing arrangements persist, giving rise to questions of obsolescence or dysfunctionality. It is important to assess the extent to which Australian transport policy is tracking these changes, or whether it is lagging. The latter can also be assessed against policy action and project implementation in international settings.

1.1.1 Transport: Operational challenges

Among the highest profile issue is the dependence of Australian cities on road-based transport and the associated traffic congestion arising from very high automobile and truck-mode shares (by OECD standards) observed in Australian cities. Although congestion is arguably a cost that is self-imposed by car users, it is a frequent point of frustration and the high proportion of travel by car means it is a popular concern to which policy is highly sensitive (IA 2018a; Productivity Commission 2017). However, road congestion is not the only pressure on transport systems, as passenger rail use has grown rapidly in recent years, particularly in Melbourne, spurring policy and infrastructure responses such as the Melbourne Metro Rail Tunnel and the Brisbane Cross River Rail project. Much current policy seeks to manage traffic growth while encouraging a shift to non-car modes. For example, the *Plan Melbourne 2017–2050* metropolitan strategy states that the share of Melbourne's travel taken by public transport, walking and cycling must increase.

Active travel has become a focus of health policy in cities as the adverse physical effects of sedentary behaviour on health and wellbeing become better understood. There is strong evidence that infrastructure investment in active travel generates high net benefits from reduced health, wellbeing and environmental costs, yet active travel budgets remain minor components of most metropolitan transport plans and strategies.

A final operational challenge for cities is managing freight and logistics flows. Demand for goods movement is growing at a faster rate than passenger travel, resulting in road congestion impacts that often have high direct externalities in terms of pollution, noise and emissions, and damage to infrastructure. As cities become more dense, their capacity to absorb growing freight flows using conventional vehicle types is becoming constrained. New approaches to managing freight within cities—particularly for the costly 'last mile' of delivery—including micro-electric and bicycle technologies are emerging globally, yet have not been extensively adopted in Australia.

1.1.2 Transport: Strategic challenges

In addition to direct system operational challenges, Australian cities face major strategic questions about the future configuration and performance of transport networks. Road-based carbon emissions are the worst sectoral contributors to climate forcing (Unger et al. 2010), yet the Australian transport sector has not yet been required to adopt systemic carbon emission reduction as a strategic objective.

Adoption of electric vehicle (EV) drivetrain technology in Australian cities lags peer nations such as New Zealand or the UK. Federal policies anticipate greater EV take-up, but major questions persist around the availability of charging infrastructure. A further strategic question about the sustainability of fuel excise revenue looms over

any EV transition. Finding alternatives to fuel excise, as a means of funding transport infrastructure, will be a considerable policy challenge in the context of limited public appetite for alternative revenue mechanisms such as systemic charging for road use.

In addition to electric drivetrains, new vehicle control technologies are expected in the medium-term that may reduce the role of human drivers in cars, while potentially having wider disruptive effects on transport systems. While debate continues about the feasibility of wide-scale uptake of autonomous vehicle (AV) systems, these will require new regulatory frameworks and potentially design changes to transport systems, infrastructure and adjacent public space. There is limited evidence that the transport policy sector has yet established clear frameworks for AV rollout, but it will likely need to provide a systematic response by the end of the next decade.

In addition to AVs are a wider set of technologically mediated new transport systems such as ride-hailing platforms, which have recently forced a reconfiguration of taxi regulation. Further systems such as digitally mediated bicycle, e-bike and scooter hiring systems have recently been visible additions to transport networks in Australia, although their substantive impact is less easy to gauge.

Broader issues beyond vehicle technologies are also demanding attention. The spatial structure of Australian cities is increasingly configured through zones of higher and lower accessibility to labour markets, reflecting differential agglomeration economies. This spatial patterning of accessibility is mediated by the transport network, with high-skill, high-remuneration employment concentrated in central city and inner-urban zones that have high accessibility by public transport and active modes. Improving transport networks so they enable more inclusive access to labour markets—both directly and by shaping urban structure to better distribute jobs—is an important consideration. Various state-led projects are attempting to respond to this problem. For example:

- Aerotropolis in Western Sydney, with new rail and medium-capacity transit connections: light rail or 'trackless trams'
- Melbourne Suburban Rail Loop
- various fast regional rail networks under consideration by state governments to improve regional access to metropolitan employment.

All of this change poses questions for transport research. There have been few overarching reviews of Australian transport policy in recent years that can support high-level strategic responses to the changes occurring in transport policy. It remains unclear what recent shifts in technology, travel patterns, technology and regulation mean for transport strategies and the options they incorporate. New research is thus needed that can offer high-level clarity around alternative options and directions.

1.2 Research purpose

This project aims to investigate how Australian urban transport programs and policies are responding to changes in transport technology, travel patterns, environmental imperatives and spatial development dynamics to offer guidance about future directions and options. The project poses four research questions:

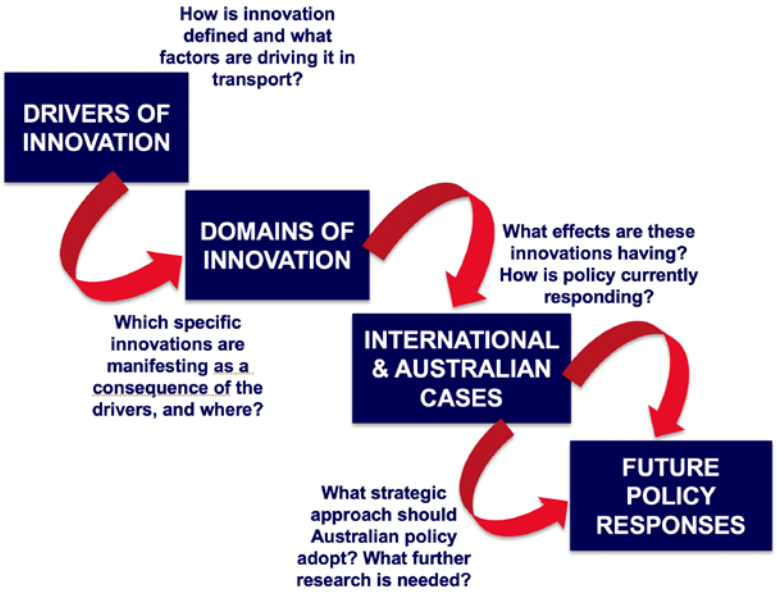
1. How are large-scale processes of technological, economic, social and environmental change affecting travel patterns and transport systems in Australian cities?
2. What strategic approaches to configuring infrastructure, technology, regulation and design are Australian metropolitan transport programs and policies adopting?
3. How do Australian metropolitan transport programs and policies compare to relevant international examples in terms of strategic approaches to technological, economic, social and environmental changes?
4. What forward positions should Australian metropolitan transport programs and policies consider in response to drivers of major transport system change and what further research is needed to inform this positioning?

1.3 Research approach

The overarching research approach is depicted in Figure 1.

The first step in examining innovation responses was to define the key drivers of innovation in transport policy —exploring how innovation is defined and the factors that drive it. This is a critical step, particularly in ensuring a comprehensive overview is achieved that is purposively grounded in the challenges Australian planners are currently confronting. Section 1 provides a comprehensive discussion of this.

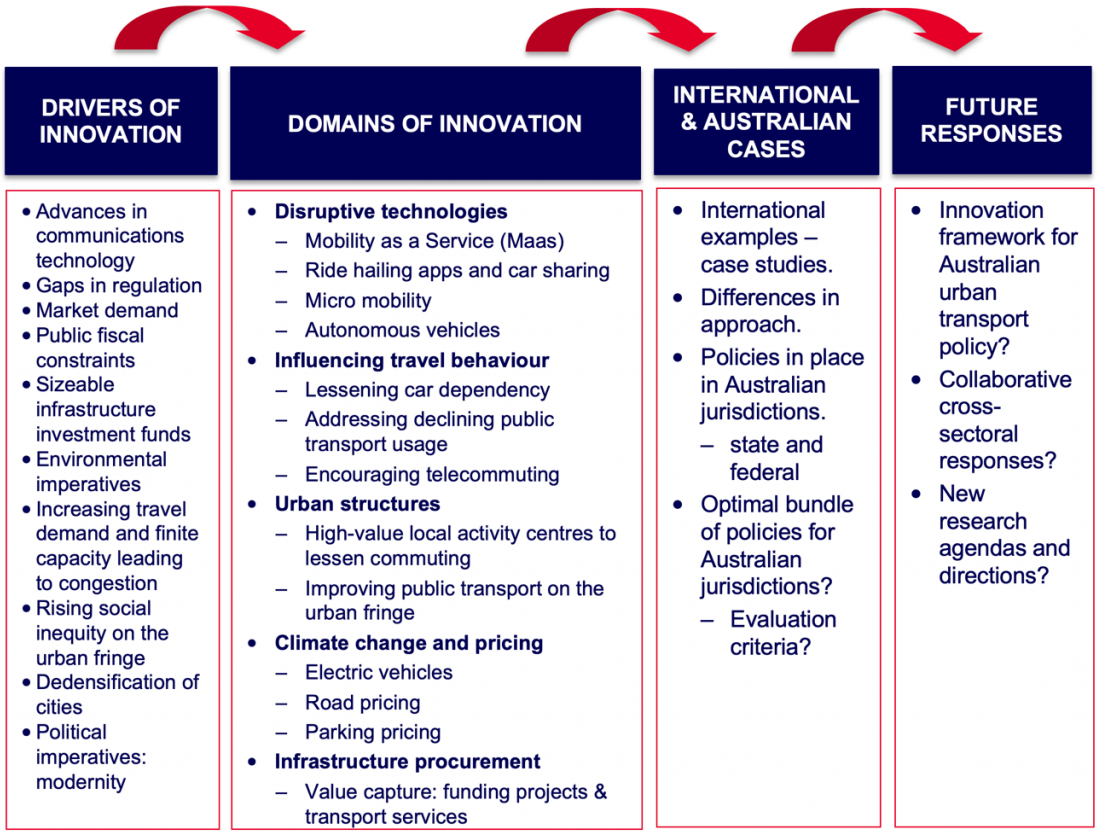
Figure 1: Conceptual framing of study



Source: Authors.

Understanding the drivers of innovation enables a categorisation of specific innovations that arise as a consequence of the drivers. These are specified as the 'domains of innovation' (Figure 2) and are employed as a means of reviewing international literature, international practice and Australian urban policy.

Figure 2: Conceptual structure of project



Source: Authors.

The research approach follows this methodology, and draws on a desk-based literature and policy review and engagement with the transport policy sector as outlined here.

1.3.1 Innovation in urban transport

This section responds to the overarching framing of the research. This study is undertaken from within an innovation perspective on urban transport. Theories of innovation have received extensive attention in recent decades as cities and economies seek to improve economic performance and address sustainability imperatives. A review of the innovation literature was undertaken to develop this perspective. This review seeks to identify appropriate theoretical framings for the investigation of transport innovations in Australian cities. This review discusses the literature on business innovation, technological innovation systems, regional innovation, sustainability innovations and transitions theories, as well as contemporary theorisations of the state as an agent of innovation through policy and regulation.

1.3.2 International transport research and policy review

This section responds to Research Question 3. A review of the international research and policy literature was undertaken to identify major large-scale forces and dynamics of change among urban transport systems. The principal source was the scholarly literature, again interrogated relative to the 'domains of innovation'. Selection of source material was via a search of bibliographic databases using Google Scholar and Scopus. This was supplemented with broader searching of the grey literature and media to identify further dimensions that had not yet appeared in the scientific record.

1.3.3 Review of transport policy in Australia's major cities

Responding to Research Questions 1 and 2, a desk-based review of recent (2014–2019) metropolitan transport policy documents for a sample of three Australian cities—Sydney, Melbourne and Perth—sought to identify major change drivers and common or divergent themes and directions. This was supplemented by a review of emerging policy interest (drawn from relevant grey literature, including federal government material). The policy review focussed on the 'domains of innovation', as described earlier.

For each policy document, a content analysis was conducted—looking first for the presence (or absence) of policy discussion for each of the domains of innovation. Then an evaluation of each innovation item was made using a qualitative rating scale to provide a sense of the direction.

1.3.4 Policy options for transport innovation in Australian cities

Responding to Research Question 4, this section considers potential policy options for transport innovations in Australian cities in terms of optimal policy bundles, arrangements and practices to support innovation development and application, and future research questions and directions for transport innovation research in Australia.

1.3.5 Project Reference Group

A Project Reference Group (PRG) was formed to give advice to the research team about the research approach, the 'domains of innovation', and to identify any emerging major observations and themes about the transport change processes.

1.3.6 Metropolitan policy and directions workshops—Melbourne and Perth

Small workshops of relevant policy practitioners were convened to respond to the outputs of the international and Australian policy review. We sought their input to test any points of controversy or divergent opinion, and to provide guidance on shaping the directions and options proposed by the project.

Workshop participants were selected based on the research teams' peer networks and on the advice of the PRG.

1.4 Report format

Section 1 serves to position our approach to understanding innovation. The report is then structured to report the research findings. This is organised by reporting on the international overview first, followed by international examples of transport and planning projects (Section 2). These are organised with each domain of innovation in turn. Then follows Section 3, which focusses on the Australian experience as understood from current and emerging policy, again organised by innovation domain. Section 4 sets out potential directions towards a framework for innovation urban transport policy in Australia.

2. Innovation in urban transport

Innovation is a major topic of investigation in contemporary social science. There is a vast literature on innovation that seeks to define, record and explain instances of innovation and the underlying social dynamics that make societies or social subgroups innovative.

Given the scale of the present project, we have focussed our attention on innovation in the sphere of urban transport and did not seek to expend effort on extensive wider discussion on the notion of innovation, definitions and the empirical studies of what makes societies, regions, cities, firms or communities innovative. Innovation debates also intersect with wider social scientific discussions, including literatures on transitions, socio-technical relationships, economic institutions and business practices. The discussion needs to recognise the rapidity with which some transportation innovations have emerged in recent years, as the literature may not yet have addressed the changes observed in practice.

Transportation technologies and systems change over time and are defining features of human advancement. The wheel, sailing ships and steamships, the railway, the bicycle, the automobile and the aeroplane are each markers of historical technological development. The contemporary era has witnessed the application of urban transport technologies in new ways and at greater scales than previously. For example, although electric vehicle technologies have existed for over a century and have been widely used in rail-based transport, their effective application at scale for road vehicles has depended on new configurations that can replace the internal combustion engine. Wayfinding technology has existed in the form of printed street maps for centuries, but their electronic combination with global positioning systems in handheld communications devices has enabled new ways of coordinating transport networks. Road tolls have existed since antiquity (Rogers 2019), but the emergence of automated electronic recording and debiting systems has only recently opened up their potential systematic application to urban networks.

Most transport technologies have existed in precursor form for long periods prior to their widespread application. Rail tracks, for example, were used in various applications prior to the steam train, while the automobile in its initial phases of development reflected historical wagon designs. Aviation is perhaps one of the few instances of new transport technology emerging in a short period without historical antecedents (except in human imaginaries). Thus, identifying what is new in a recent transport technology is not clear-cut.

Of course, the value of innovation is not only about newness and novelty as such, but the creation of value propositions for regulators, providers and travellers.

In terms of transport, such value propositions for regulators can mean enhanced ability to meet overarching policy goals such as:

- reduced emissions and congestion
- increased productivity
- increased accessibility
- social equity.

For providers, the value proposition can include:

- greater efficiency
- greater capacity
- greater market share.

For passengers, the value proposition can include:

- increased usefulness
- increased accessibility
- increased inclusivity
- increased comfort
- increased convenience
- increased safety
- reduced price.

For all three, there are also important symbolic dimensions associated with being seen to be, by turns, sustainable, best-practice, status-enhancing and innovative for their own sakes, whether or not all of these symbolic dimensions align with each other and with the various value propositions in terms of measurable outcomes.

Transport technology is also place-specific. Transport technologies may exist in one place for a long period before they are applied in other places. The *shinkansen* high-speed train was first designed and operated in Japan based on previous rail and aviation technology. But its application in Australia, for example, would be considered innovative. The ascription of a technology as innovative in transport is thus temporally and spatially conditioned.

Similarly, not all innovations may be considered as technologies. New approaches to design and regulation, to policy and planning or to institutions, may be viewed as comprising innovations if they lead to better transport outcomes for users, suppliers and regulators. However, that appreciation requires recognition that there may be an element of subjectivity around innovation. In Melbourne, the move to franchising of public transport services may have been described as novel, given the legacy of direct public delivery; however, not all observers considered that this approach improved services or public value (Mees 2005), even as it has delivered value for franchisees. The debates about the uptake of automobiles and the configuration of land-use planning and design in the period after WWII show that practices and technologies that may be perceived as innovative at one time may also be assessed as retrograde once their wider consequences and contradictions become better understood.

This report is not able to provide a comprehensive review of innovations at different times and places, nor the debates that surrounded them. Instead, this report seeks to survey a selected set of transport innovations that are currently occurring and assess their effects, a sample of international policy responses to them, and to discuss the implications of these relationships for urban transport in Australia.

2.1 Framing transport innovation

This project seeks to understand innovations in transport in Australian cities, which in turn requires an engagement with the literature on innovation and transport. We undertook a literature review of innovation theory and its relevance to transport systems, policy and regulation. The innovation literature is vast and, while informative, is not necessarily oriented to the questions posed by this research.

It is appropriate to consider definitions of innovation. The term *innovation* has been highly debated but typically refers to new technologies, systems or practices within social and economic domains. In relation to transport, Giannopoulous and Munro (2019: 5) began with Schumpeter's suggestion that 'innovation is the commercial exploitation of new ideas', although they then extend this definition to an extensive multifaceted description that defies easy encapsulation. Feitelson and Salomon (2004: 12) suggested that 'transport innovation' includes both new ways to manage transport systems via various policy tools as well as new technologies, a prescription that is endorsed by Ongkittikul (2006). Marsden (2011: 2 ; see also Diewald 2001) suggests innovation is 'the development and application of something new'. Hekkert et al. (2007) adopted a process definition, such that innovation comprises the development of technology in interaction with the system in which the technology is embedded. For Hekkert et al. (2007: p.pp414) an innovation is defined as 'the successful combination of hardware, software, and orgware, where orgware refers to the various components of the innovation system', with *orgware* being the wider institutional formation within which innovation occurs.

In this report we define innovation as 'the conception and application of new technical, social, organisational, institutional or economic practices that respond to societal demands or needs'.

The focus of this research is on drivers of innovation and the policy responses on the part of Australian governments in the context of international as well as domestic patterns. If we adopt, for the purposes of argument, that innovations follow a linear path in which they are developed and then emerge into practical application and are then exposed to market and policy responses which may result in their specialist or systematic adoption (or their failure), then the orientation of this project is on the policy responses.

The concern of the project is less about *where* and *how* innovations emerge, but rather with the trajectory they undertake once released into the Australian urban context.

Nonetheless the project is interested in *drivers* of innovation, which are defined here as the social, economic, environmental and institutional conditions that generate market and policy demand for innovation, and the dynamic response between this demand and suppliers. The conceptualisation of drivers of innovation is discussed in synthesis below.

The remainder of this section offers a brief overview of the innovation literature in terms of its relevance to policy and to transport systems. This perspective attends to innovations that have already emerged.

2.1.1 Innovation systems

There is a broad literature on innovation systems at the firm and spatial scale. The literature on technological innovation and the mechanisms by which it is distributed and adopted can be considered, in terms of this research, in two ways.

First, there is an extensive literature on technological (product) innovation at the firm level, focussing on how individual actors develop innovative technologies that are commercially competitive within consumer markets (Reinhardt and Gurtner 2018). That literature typically considers such factors as internal organisational strategy and dynamics, including the mix of skills, operational structures or procedures, and the role of capital. In some instances this literature also extends to consideration of innovative business models that may involve technology but which also draw together means of financing as well as organisational forms and new ways of engaging and coordinating labour. This literature is prominent in discussions of innovation but, as Suurs et al. (2009) argued, it is dominated by a linear framing, in which basic research informs applied R&D, resulting in a new product that is then diffused through user sectors. While some novel business models have been observed within the transport sector in recent years, such as platform-based ride-sharing or dockless bicycles, the focus of the present study is not on how they arose as either an innovative technological or business model. Hence the research does not directly consider this aspect of innovation.

Second, a spatial and institutional literature considers the dynamics of overall sectors, focussing on technological innovation systems (TIS) and factors that contribute to the productivity of wider collectives of institutional actors including networks of firms and value chains (Andersson et al. 2018; Carlsson and Stankiewicz 1991; Hanson 2018). This literature is one of the most prominent in innovation debates. There are two elements to this literature; one that focusses on the systems of technological innovation, and another that emphasises spatial dimensions, such as at the national (Chung 2002), regional (Cooke 2001; D'Allura et al. 2012) or even local (Muscio 2006) scale. Hekkert et al. (2007) argued that innovation systems are important determinants of technological change. They suggested that innovation systems should be understood as encompassing not only individual firms along with technology characteristics but also 'all institutions and economic structures that affect both rate and direction of technological change in society' (Hekkert et al. 2007: 415). They cite Freeman (1987 n.p) who described an innovation system as 'the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies'. Suurs et al. (2009) similarly observed that the development and diffusion of an emerging technology is determined by a system comprising actors, institutions and technologies that are interrelated.

This 'structure of the system', Suurs et al. (2009) argued, may take time to develop as the technology emerges. Hekkert et al. (2007) suggested that innovation systems should have goals, such as to develop, apply and diffuse new technological knowledge. Hence Hausknost and Haas (2019) suggested that the goal of an innovation systems perspective should be to identify points of policy intervention aimed at enhancing the overall performance of the system, or to stimulate particular types of innovation—such as in relation to sustainability. However, Hausknost and Haas (2019) also suggested that this perspective can be overly focussed on market processes of technology diffusion and insufficiently attentive to wider societal goals towards which market selection processes may be incompatible. A notable feature of the TIS perspective is that it recognises that the private sector is not the only potential source of innovation, and that other actors in the system can be influential in shaping the kinds of technology that arises.

Moulaert and Sekia (2003) have suggested that the term 'territorial innovation models' can be productively applied to innovation systems with spatial dimensions. This literature is typically policy-oriented, as it seeks to identify the measures that governments can pursue that will foster innovation systems within their jurisdiction, typically at the sub-national scale, though for some instances a national innovation system may be conceivable (Chung 2002; Cooke 2001). Elements of this spatial innovation literature are relevant to the present study, as many transport innovations have a regional dimension to them, such as ride-sharing and bike-sharing schemes. However, like the intra-firm literature, the spatial innovation literature is focussed on regional institutional factors that largely facilitate product innovation and its adoption within markets, and are much less attentive to the regulatory shaping of innovation uptake. For this study, we largely avoid the firm and regional-level innovation literature and concepts, as it focusses principally on the generation of technological innovations and their uptake.

2.1.2 Socio-technical transitions

A substantial literature on socio-technical transitions focusses on the social and technological processes through which innovations occur and are disseminated within societies and economies. In many cases in history, new methods or technologies have emerged and been adopted. Transport has been a major sector where technological transition has been especially prominent, such as the emergence and adoption of the railway, the steamship, the aeroplane or the automobile. Within this literature, various authors (Geels 2002; Rip and Kemp 1998) have offered concepts and frameworks for understanding how existing technological systems shift to new arrangements. Rip and Kemp (1998) suggested that at a given time societies operate within a given socio-technical 'configuration' of technologies and artefacts that comprise a 'socio-technical landscape'. Geels (2002) adapted Rip and Kemp's concepts to develop an influential systemic view of socio-technical change in the transport domain, using as an example the transition from sail to steam-powered ships for oceanic trade. Geels (2002) subsequently advanced a framework comprising technological niches that emerge within socio-technical regimes that in turn are nested within a wider socio-technical landscape, often involving multiple actors. In this framing, extant socio-technical configurations are set within 'landscapes' that are deep structural trends. Such landscapes in transport might include oil prices, geopolitics, consumption patterns and political arrangements.

Regimes refer to semi-coherent sets of rules covered by social groups, such as regulatory and policy systems or contexts. Innovation, Geels (2002) argued, occurs in 'niches' that are protected from normal market selection and may be incubated before they emerge in wider use. Niches may also provide for social configurations that support innovation, such as supply chains or user–producer linkages (Geels 2002).

When combined, these concepts offer a 'multi-level' perspective (MLP) on innovation that allows pathways to be identified through which innovations travel from emergence within niches to positioning within adapted or novel regimes. Such pathways are termed 'technological transitions'. These transitions:

- may occur from the bottom up, whereby a niche technology performs better according to the parameters of the regime
- may occur because the landscape shifts and opens up potential for niches to flourish.

While the transitions literature does not necessarily use the term 'drivers' to describe the landscape conditions that structure the potential for innovations to emerge and be adopted, following Whitmarsh (2012) the term is consonant with the notion of drivers that this study has been asked to investigate.

The socio-technical transitions literature has been linked with innovation systems through efforts to understand how transitions can be enabled by the shaping of such systems. Much of this literature is framed within notions of sustainability, which is viewed as a major social, economic and environmental challenge. For example, Jacobsson and Bergek (2011) argued that in the case of particular societal challenges, such as climate change, technology -specific policies are needed to advance transitions towards sustainability. They contend that governments need to assess how innovation systems are performing in relation to sustainability transitions based on technological innovation and intervene where system weaknesses impede transition. Coenan and Truffer (2012) argued that such transitions may also be spatial, as they occur within particular territorial contexts. They argued in favour of a spatial perspective on sustainability transitions to understand the particular geographical conditions under which certain innovations succeed or fail, including particularities of context. This understanding is relevant to transport innovations in cities, which may develop more successfully in some places rather than others. For example, cycling has flourished in some European cities over the past three decades, while it has languished in many Australian cities, niche efforts notwithstanding. There is also local variation such that shared bicycle schemes have been adopted in some Australian cities, such as the Gold Coast, but were rejected in the case of Melbourne.

While its initial conception referenced transport systems, much of the socio-technical transitions literature has focussed on other technology sectors. However, Whitmarsh (2012) investigated the MLP on sustainability transitions in relation to transport systems, and argued that it provided a useful framework for understanding attempts to institute shifts towards sustainable transport modes. Whitmarsh (2012) suggested that niches could be seen to be in tension with extant regimes. Whitmarsh also cautioned that there are limits to the insights from the MLP for active efforts to transition transport systems towards sustainability, as the original focus of the MLP was historical and linked to consumption of more technology (and often fuel), whereas contemporary efforts often try to reduce technology and fuel use. Nonetheless, the deployment of landscapes as 'drivers' within the MLP offers a useful background framing for the present investigation and will be developed further later.

Further dimensions of sustainability transitions have been assessed, such as Carvalho et al. (2012) who apply a sustainability innovations and transitions frame to examine green innovation in urban transport in Curitiba, Gothenburg and Hamburg. They argued that 'green urban transport policies' in these specific geographical contexts are factors that influence the kinds of technology adopted within the regions' transport systems. However, to the extent that technological transition occurs, Carvalho et al. (2012) suggested that it happens in accordance with local geographies rather than demonstrating a universal pattern. This observation is productive, as it suggests that there are likely to be local variations in the way innovations can emerge and how they are governed and regulated.

In a similar vein, Klitkou et al. (2015) cautioned that transition processes often face contrary dynamics that 'lock-in' existing technological configurations. They suggested that once established, a regime has a stabilising effect on innovation dynamics and prevents the establishment of new innovation trajectories. They argued that such effects as economies of scope, network externalities, increasing informational returns, technological interrelatedness, collective action and institutional learning effects may contribute to lock-in, preventing innovation transition (Klitkou et al. 2015). However, they also cautioned that lock-in may also have countervailing effects, such as petrol stations that typically support fossil fuels potentially being converted to support a biofuel or hydrogen transport.

Although it offers a loosely normative framing of innovations that support sustainability transitions, this literature offers only a limited *prescriptive* direction for government (Bening et al. 2015; Wieczorek and Hekkert 2012). While the literature offers broad guidance on constructive measures, it is not typically policy-oriented in offering a guide to government in responding to emergent innovations. Hence Kern and Rogge (2018) suggested that transitions scholars have made insufficient use of public policy theories, although they don't delve into considerations of regulatory frames. Auvinen and Tuominen (2014) argued for a long-term perspective on transitions, referencing the need for foresight processes that bring actors together for long-term transition visioning. Wieczorek and Hekkert (2012) argued that the TIS require a 'systemic policy' framework that maps a policy cycle against cyclical innovation dynamics, while offering specific policy tools that can enable and enhance innovation.

While it may only offer moderate guidance to government on how to enable sustainability transitions, this literature also does not offer specific programmatic guidance to government on how to manage innovations that may emerge, are adopted but are disruptive and contravene prevailing regimes. The example of micro-mobility innovations, such as electric scooters might be considered in this context. These have been rolled out globally by private providers, often in contradiction to existing regulations pertaining to motorised vehicles. So, while it offers a valuable insight into the processes through which sustainability transitions based on innovation can occur, the sustainability transitions literature is of less use in recording and assessing the performance of innovations as they emerge from a public sector perspective.

2.1.3 Public innovation and response

A further literature on wider adoption and distribution of innovation in the public sphere focusses on the policy and economic settings that enable innovative private sector activity, as well as attention to the processes and dynamics through which public institutions can resolve major policy problems or dilemmas. For example, Sharif (2006: 745) considered how the public sector could establish a national innovation system as (pace Metcalfe 1995) a 'set of institutions that (jointly and individually) contribute to the development and diffusion of new technologies'. This literature shares many similarities with the regional innovation debates described earlier (2.1.1), although in the present case the focus is more on the public policy engagement with innovation than with sui generis dynamics implied by the former. In some instances the literature examines innovations in governance itself (Moore and Hartley 2008), although this is rarely applied to the transport domain.

Some attention has been given to the role of government in facilitating 'open innovation' (Kankanhalli et al. 2017). This has been reflected in studies considering transformations of the European Car Industry by Dodourova and Bevis (2014) and MacNeill and Bailey (2010), who favoured an 'open innovation' model in grappling with firm-level demands of transformation of automotive design and manufacturing. Köhler et al. (2013: Figure 1) provided a detailed diagrammatic depiction of the innovation system within the European automotive sector, drawing on TIS socio-technical transitions theory. They described the automotive innovation system with overarching dimensions orienting towards market and regulation, with drivers including consumer and business demand along with framework conditions, such as the financial and taxation environment. Linked to these are the industrial system of vehicle producers into which the educational and training systems are connected. Also linked to both the industrial system and the educational and research system are the political system of European and national governments, plus various policies across research and development and environment and climate. An explicit 'innovation infrastructure' is also described including such elements as standards frameworks, R&D subsidies, patenting and venture capital (Köhler et al. 2013).

The attention to policy is not only in terms of 'systems'. Beise and Rennings (2005) considered how environmental regulation can generate 'lead markets', which then enable local firms to develop within a constructive local context and then export their environmental innovations to other jurisdictions. Schade (2016) adopted a 'sectoral innovation systems' approach to understand how German high-technology policy was applied to the mobility sector within the context of wider European innovation and transport policy, principally the Trans-European Transport Networks (TEN-T) directive. That scheme combined infrastructure investment with new technical standards across such domains as decarbonisation, multi-modality, safety, external costs, security, resilience and telematics (Schade 2016). Europe's leading global performance in the patenting of mobility innovation was, Schade (2016) argued, a reflection of this regulatory and investment model. Cré et al. (2012) reported on a project that sought to stimulate a debate on urban mobility innovation across multi-sector stakeholders in a multi-national (European Union) context. Through this project's analysis of success factors and barriers of urban transport innovations, local stakeholders reported capability to better understand innovation in concept and implementation.

The role of public sector organisations in supporting and facilitating innovation has also generated a notable literature. Central to this discussion is the work of Mazzucato et al. (2019) on the way that public sector organisations can enable innovation. Mazzucato et al. (2019) suggested that a public sector 'mission-oriented' approach to industrial policy can provide directions about future growth areas and catalyse activity that would otherwise not occur, such as in relation to the globally agreed Sustainable Development Goals. They argue that such 'grand challenges' give policy-makers the opportunity to determine the direction of growth by making strategic investments across different sectors from which the private sector may develop further. They argued this 'market-shaping' does not imply 'top-down' planning, but heightens business expectations about which areas are likely to grow, and catalyses activities that would otherwise not happen. Grand challenges, they argue, should be cross-sectoral and involve positive feedback loops to ensure firms and policy-makers make analytical connections. They offered the example of 'A Plastic Free Ocean' as a grand challenge under the Sustainable Development Goals and set out how varying sectors and sub-sectors can contribute to the goal, including the chemical industry, biotech sector, AI sector, and design and waste sectors collaborating around various mutually supportive initiatives (Mazzucato et al. 2019). However, this framing presumes a prospective and preparatory approach to shaping markets for grand innovation; it does not offer a clear way for policy to respond to innovations that have already occurred.

Further questions as to how the public sector can be organised to support innovation have been investigated by Karo and Kattel (2013). They argued in favour of the notion of *policy capacity* in understanding complementarities and mismatches between the public and private sectors around innovation. Such capacity, they suggested, is reflected in three policy choices:

- in relation to technological change
- in relation to the financing of economic growth
- the policy choices of public management to deliver on the preceding choices.

This theorisation is more macro-scale in approach, focussing on the ability of the state to achieve appropriate outcomes supported by both policy and administrative capacity. In a later discussion Karo and Kattel (2016) argued that differing organisation capacities are necessary to support and enable innovation, and note that there is more organisation variety within the public sector than is typically assumed by theories that focus on the inflexibility and unresponsiveness of monolithic state bureaucracies. They concluded that contextually embedded organisation variety can improve policy performance, yet accept that there is not yet sufficient empirical material on this topic. There is very little literature on transport in relation to open innovation.

A final literature that deserves attention is the notion of 'living labs' as a mechanism for bridging private and public sector divides around innovation. Living labs describe interaction arrangements between public, private and non-government stakeholders 'collaborating for creation, prototyping, validating, and testing of new technologies, services, products, and systems in real-life contexts' (Leminen 2015: 2), typically with a sustainability objective (Nesterova et al. 2017).

Living labs have been described as a form of experimental governance, whereby urban stakeholders develop and test new technologies, products, services and ways of living to produce innovative solutions to the challenges of climate change, resilience and urban sustainability (Voytenko et al. 2016). The concept of living labs has proliferated over the last decade especially via EU innovation and urban policy (Marvin et al. 2018).

To the extent that living labs have been applied in relation to transport, they have tended to focus on urban logistics and freight. Hence Nestoreva et al. (2017) described the objective of city logistics living labs as seeking to foster long-term cooperative relationships between local authorities, industry, and academia, to enable proactive implementation of sustainable logistics measures. This is viewed as a process that better allows for experimentation and negotiation in contrast to conventional 'solutions-based' processes. Quak et al. (2016) described a city living lab organised around the notion of 'freight partnerships', which involve freight stakeholders meeting regularly (either formally or informally) to discuss issues and problems in the urban freight area. Lindholm and Browne (2013) described such partnerships as involving a shared objective, a management and action plan to oversee proceedings, and 'soft' outcomes, such as information exchange, or physical outputs, such as new regulations or designs. Examples cited by Lindholm and Browne (2013) included the Paris City Council *Good Practice Charter for Transport and Delivery of Goods* and the Utrecht *Committee for Distribution Affairs*.

The regulatory and governance challenges posed by emerging transport technologies are reflected in observations by Stone et al. (2020: 1) who noted that 'new economies based on emerging technologies for shared mobility and AVs will shape future urban transport systems, but their potential impacts are uncertain'. Drawing on interviews with public and private sector actors in urban transport in Australia, they explored the difficulties that government agencies face in planning and regulating the deployment of new technologies for the public good, while simultaneously encouraging private sector innovation, which is also seen as a public good. They noted that 'being both a facilitator and an umpire is not an easy task' (p.2). The paper notes how all private sector respondents had concerns for their businesses under conditions of uncertainty and wished to avoid natural monopolies emerging. The private sector interviewees also acknowledged that strong and clear government regulation is seen to be necessary to allow the sector to reach its maximum potential and have positive ramifications for both the public and the private good. Stone et al. (2020: 1) also raised questions about the capacity of government agencies to effectively manage these complex transitions.

2.1.4 Framing the present study

The prior discussion has assessed how the innovation literature can inform understandings of transport innovations in Australian cities. While the review has covered a broad swathe of discussion about the nature of innovation, the conditions that foster it and the ways that governments can and should respond to innovation, there remain significant gaps in knowledge about transport innovation. Most of the literature treats innovation as the objective of organisational, economic or governmental arrangements. In contrast, there is much less literature on how governments might grapple with innovations that appear and are subject to pressure to be introduced to transport systems.

In the context of this study, what is sought is a better understanding of how governments could or should respond to innovations as they emerge and whose proponents press for their adoption. Such understanding would be agnostic about the origins of innovation and would merely seek to appraise the potential and actual effects of innovations on the transport network, as well as wider consequences for society, the economy or environment.

For example, the rollout of ride-sharing operations was not of interest to governments in Australia on account of the processes of innovation that produced the new business and employment model that is central to the sector. Rather, the response by government was concerned with managing the safety implications of unregistered taxi services alongside the systemic effects on the wider regulatory environment for taxis and, in some cases, on the broader performance of the transport system. Similarly, car-sharing services have not been a concern to local governments because of the processes of innovation that generated them; rather, governments are concerned with their effects when parked on local streetscapes and the potential for complaints from or conflicts with other parking users.

To address the gap in the literature, the project constructed a framing that can understand how innovations arise and become established in niches before widening their operational use within the transport system. This framing draws on the original project brief, which used concepts of 'drivers' of innovation. We have further drawn on the literature around socio-technical and sustainability transitions to inform this conceptualisation.

In this project, innovation is viewed as occurring via four stages.

First, drivers of innovation exist, which establish background pressures on transport systems.

Second, these drivers then exert influence on sub-domains within the transport system to adopt innovations.

Third, adoption of innovations occurs.

Fourth, policy institutions respond with new frameworks and regulations. These phases are elaborated below.

Finally, stabilisation occurs as the innovation becomes normalised or recedes.

These patterns are described in further detail below.

Drivers of innovation

We consider that *drivers of innovation* are social, economic and institutional configurations and conditions that create pressures and demands for changes in the transport system. Such changes include new means of transport to be conceived, designed and introduced into transport systems, as well as shifts in the demand for and accessibility of various modes of transport in relation to changes to land-use distribution and associated activity spaces. They are similar in character to the 'landscape' factors articulated by Geels (2002), but involve a greater sense of pressure on the system rather than Geels' wider, more general framing. Drivers could include:

- changes to mobility demand
- changes in energy supply and prices
- availability of large-scale finance
- system capacity constraints
- environmental imperatives
- urbanisation and land-use changes within urbanised areas
- political and institutional dynamics.

These drivers are not necessarily identifiable *a priori*.

Domains of innovation

The drivers of innovation exert influence on *domains of innovation*. These are socio-technical sub-sectors of the overall transport system in which new technologies, regulations or strategic frameworks emerge and are applied. They are similar to 'niches' in Geels' (2002) framework but may also comprise general cross-system issues, such as road pricing (IV 2020) or public-transport network planning (McLeod et al. 2017), in addition to issues that are small and particular in scale, such as shared electric scooters or policies about road classifications and roles related to land uses.

Adoption phase

The *adoption phase* is where innovations are introduced into the transport system. This may be via market uptake and distribution, as in technological innovations such as electric vehicles or smart cards allowing access to multiple modes. Adoption may also include interventions by government, such as application of a road pricing or fuel excise regime, or regulatory and design innovations that change the allocation of public space between different modes, creating the conditions for further technological innovation related to changes in user behaviour that arise. Adoption may be disruptive, but that effect is not necessarily the case.

Policy response phase

During the *policy response* phase, governments act to manage, shape or influence the new technology and the behaviours that accompany it. This may be by instituting new regulations to ensure public safety, as in the case of innovative micro-electric mobilities, or by supporting rollout of new infrastructure, as in the case of EV charging technology. Further government responses might be to introduce or amend regulatory regimes, such as in the case of ride-hailing applications.

Stabilisation phase

A final *stabilisation* phase might be observed, in which there is a regularising of both the innovations within the context of their domains and wider drivers, as well as stability in the regulatory and policy environment. At this point, government responses are more measured and there is an element of monitoring and evaluation.

Together these five stages comprise a general sequence of innovation. This may be a linear process, as the stages are distinctly observable. However, the pattern may be less discernible in practice as the nature of innovations can tend to more complicated processes, where phases occur simultaneously or are reversed or exhibit further patterns. The literature is replete with descriptions of innovation processes that are multi-dimensional, multi-sectoral, multi-actor and multi-dimensional. As Giannopoulous and Munro (2019: 20) noted, 'a major segment of the transport sector can best be characterized as a complex , multidirectional , feedback-driven, and dynamic innovation process'. While it is important to recognise complexity in innovation processes there is a necessity to ensure that such descriptions do not impede the obtaining of value for policy reflection. Hence in this project there is a trade-off between analytical complexity and applicable simplicity.

3. Domains of innovation: International review

- Five ‘domains of innovation’ are identified, with an overview of the issues and of international practice in each domain provided, based on the international research literature.
- Many innovations may be considered innovative in some contexts but not in others. For example, approaches to improve public-transport network planning may be considered innovative in Australia but not in European countries where they have been widely implemented since the 1970s.
- A broad diversity in the type, extent and novelty of innovations is observed. Some domains focussed on technology exhibiting recent developments while others involved institutional development often evolving over long time periods.
- Information and communication technology ‘platforms’ have come to prominence as innovations in transport systems internationally. These have proven attractive to users, but they also bring complexity in terms of innovations in institutional and policy responses.
- Some innovations seek to alter travel behaviour. Many of these reflect longstanding policy objectives; however, commitment to achieving policy objectives is often undermined by wider weaknesses in the transport policy and governance system.
- Innovative approaches to urban structure remain a policy vision in many jurisdictions but have not been adequately supported by robust policy and regulation.

- **Pricing of transport systems remains an innovation aspiration in most jurisdictions despite a strong knowledge base on technical aspects of pricing. Key issues in this domain are institutional and political in nature.**

- **Infrastructure funding via value-capture mechanisms may be considered an innovation in some jurisdictions, such as Australia, where it is relatively unknown, whereas in other places it is used regularly to fund infrastructure.**

This section investigates transport innovations in the international context. The discussion focusses on five domains of innovation that were selected through discussions within the Project Team and with the PRG.

Transport service platforms, including Mobility as a Service (MaaS), ride-hailing apps and car-sharing, micro-mobility and autonomous vehicles.

Influencing travel behaviour, including reductions in car dependence, addressing declining public transport usage and encouraging telecommuting and greater localisation.

Urban structures, including encouraging activity centres to lessen commuting and long-distance and motorised travel for everyday activities, and improving public transport on the urban fringe.

Climate change and pricing, including electric vehicles for private as well as public transport, road pricing and parking pricing to reduce travel demand and encourage a shift to low-carbon mobility.

Infrastructure funding, including major projects and transport services.

Domains are considered as sectors or sub-sectors that combine elements of social or economic drivers for change with emergent or potential technological or institutional configurations that can respond to these drivers. Not all potential domains are considered by this project. The selected domains were chosen to give a diversity of sectoral and typological framing. This recognises that while innovation is often framed in popular and industry debates as a technological phenomenon, there are many aspects of urban transport system transformation that can be considered innovative but that do not necessarily depend on technological change for their application. For instance, generalised distance-based road-pricing regimes are feasible based on existing technologies, but societal concerns about distributional and privacy consequences and political sensitivities around these have so far militated against their adoption except in very circumscribed contexts. There is a crucial task for policy-makers to understand that overcoming institutional and political barriers to desired transport system change can comprise innovation.

Within this section, *domain* is considered in terms of the innovation model used in this report, namely the drivers of change and the consequent process of adoption observed, as well as policy responses and salient aspects of the stabilisation phase. Domains have been identified as broad categories of urban transport policy, practice or operation with some degree of change imperative within or pressing upon them. An overview of the issues and of international experience and practice in each domain is provided, focussing on the scholarly and grey literatures. Discussion in this section is followed by the Australian experience and policy response detailed in Section 4.

3.1 Innovation domain: Transport service platforms

Information and communication technology 'platforms' that efficiently generate as well as coordinate economic or social activity have come to prominence and become widespread in recent years. There is a great deal of diversity in platforms, whether operating systems for specific technology ecosystems such as smartphone operating systems; in large conglomerate information systems such as Facebook or Google; or in specific applications such as Uber. In the urban transport domain, digital platforms have become prominent as mechanisms for coordinating service delivery, including integrated mobility services, car-sharing, ride-hailing and micro-mobility vehicles. Platforms are also being developed to provide AVs, although these are not in general use at present. This section discusses four platform examples:

- Mobility as a Service
- ride-hailing and car-sharing
- micro-electric mobility
- autonomous vehicles.

3.1.1 Mobility as a Service (MaaS)

Summary

Key issues pertaining to MaaS include the governance of coordinating a multiplicity of stakeholders and service providers at different levels of the decision-making process; ownership of the platform; selection of modes to be offered in a MaaS package; whether full coverage can be provided in ex-urban areas; and, segmentation by groups and modes and issues of cross-subsidy.

Domain discussion

The term Mobility as a Service (MaaS) was coined by Hietanen (2014) to describe business models and platforms that treat the whole transport sector as a cooperative, interconnected sustainable mobility ecosystem, providing services tailored to the needs of customers. In essence, MaaS consists of the whole suite of public and personal transport information and service options available being accessible to customers through a single digital platform (typically a smartphone app) with point of payment at use, either through membership subscription or one-off payments.

The innovative intent of such an arrangement is to offer the entire mobility system as an integrated and publicly accessible *service*, in contrast with existing arrangements that:

- are often not connected across sustainable modes
- typically lack a digital integration platform
- do not encourage users to optimise transport modes in favour of sustainable mobility.

Also, existing platforms often don't integrate recently emerged modes such as electric micro-mobility, car-sharing or ride-hailing. Hence MaaS is not only about traditional public transport, but also newer 'disruptive' modes that could play a part in the trip chains. In discussing the prospects for MaaS, Hensher (2017) focussed on customer experience and distinguishes a spectrum between private (personal) and public (mass) offerings: a private point-to-point based car service (such as Uber, Lyft, BlaBlaCar and RydHero [for children]); a public, largely bus-based option, that may include smart bookable 'end-to-end' services that draw upon a different pool of vehicles; or in very low-density areas at the urban fringe, a default to a car-based offering.

Typically MaaS is conceived as a single seamless offering that combines different types of mobility services accessed through one digital platform (principally a smartphone), so as to offer a demand-responsive alternative that begins to approximate the convenience of travel for long-distance journeys by private car in uncongested road networks (Finger and Audouin 2019; Jittrapirom et al. 2018; Sochor et al. 2018). The aspirations of MaaS are

usually bold: to offer a transport service that cuts user transaction and access costs, improves the efficiency of the overall network and reduces congestion (Hietanen 2014). In most systems, users pay through a subscription account thus providing a degree of fixed cost that has similarities to the fixed cost of car ownership, public transport season tickets or membership fees for car-sharing services. MaaS is a fluid concept, offering not only transport for people but also goods, and a multiplicity of modes on a 'plug-and-play arrangement'.

The drivers of MaaS include the:

- demand for improved sustainable urban mobility
- emergence and expansion of app-based access to ride-hailing and car-sharing
- availability of digital platforms that are able to combine service information, geolocation, service hailing and allocation, and payment into a single application operating on a digital device, typically a smartphone connected to the internet by high-speed mobile telecommunications networks.

Implicit within the service offered by MaaS is an institutional arrangement whereby service providers agree to their relationship with users to be mediated via the application and platform.

The modes that can be legitimately offered as part of a MaaS package—as opposed to a single project—have been debated in the international literature. For example, Ditmore and Deming (2018) asserted that MaaS providers should consider van-pooling as part of their demand-responsive set of offerings, and hence also illustrating a recurrent theme within this report—the interconnectivity of the topics—by raising the concept of shared as opposed to ownership-based modes, which is also dealt with as a topic in its own right.

The feasibility of MaaS in less-populated areas presents a challenge. Within the context of rural Sweden, Eckhardt et al. (2018) highlighted the opportunities and challenges of MaaS in meeting transport needs in terms of collaboration, services and markets, planning and decision-making, and technology and information.

Sochor et al. (2018) noted that the MaaS sector is highly fluid, as is the plethora of definitions; with a common and inevitable disjoint between policy goals and market-led initiatives. They distinguish between four levels of MaaS within a hierarchy: 0 is no integration, 1 is integration of information, 2 is integration of payment, 3 is integration of services, and 4 is integration with broader societal goals. In seeking to streamline the theoretical construct that is MaaS, Giesecke et al. (2016) outlined four issues for resolution:

- the nature of travel—including purpose, mode, means, distance etc.
- MaaS interoperability within intelligent traffic services
- the end-user perspective, with a focus on user attitudes and behaviours;
- sustainability—including work during the journey, as well as not travelling at all (e.g. teleworking).

Governance

Although MaaS is typically accessed by users via a digital platform, the key innovation of the concept is in its institutional integration. Audouin and Finger (2018) noted that while technical platforms have a key role to play, the wider potential of MaaS is enabled by the governance of coordinating a multiplicity of stakeholders at different levels of the decision-making process.

Noting that innovation comes in the form of innovative governance—as well as innovative technologies—Andouin and Finger (2018) asserted that MaaS needs to be developed as two parallel streams or mechanisms:

- **Stream I** mandates strong overall vision and dedicated legislation
- **Stream II** allows for the trialling and development of individual solutions to ensure the balance between setting a stable regulatory platform and allowing for private sector initiative.

Andouin and Finger (2018) saw this as the only way that MaaS platforms can evolve. Undertaking Stream I *and* II mechanisms clearly presents challenges: at what point should the state regulate, and on what basis? At what point will the state always be able to regulate?

The modes that can be legitimately offered as part of a MaaS system (as opposed to a single project) is a subject for debate. Ditmore and Deming (2018) used the seldom-cited niche market of van-pooling to discuss how the MaaS chain could be expanded to accommodate the requirements of less conventional trips. They conclude that MaaS providers should consider van-pooling as part of their demand-responsive set of offerings, and the van-pool concept could offer a unique perspective in potential market adoption.

Stone et al. (2020) noted that 'new economies based on emerging technologies for shared mobility and AVs will shape future urban transport systems, but their potential impacts are uncertain'. Stone et al. draw on interviews with public and private sector actors in urban transport in Australia, and explored the difficulties that government agencies face in planning and regulating the deployment of new technologies such as MaaS for the public good, while simultaneously encouraging private sector innovation, which is also seen as a public good. The authors noted that 'being both a facilitator and an umpire is not an easy task'. Stone et al. (2020) noted how all private sector respondents had concerns for their businesses under conditions of uncertainty and wished to avoid natural monopolies emerging—although presumably not if their firm becomes the beneficiary. The private sector interviewees also acknowledged that strong and clear government regulation is necessary to allow the sector to reach its maximum potential and have positive ramifications for both the public and the private good. The Stone et al (2020) paper helps focus attention on which forms of regulation might be required by industry. It also raises questions about the capacity of government agencies to effectively manage these complex transitions.

Jittrapirom et al. (2018) proposed an adaptive governance approach to enable implementation by managing the uncertainty relating to technology, demand, and the willingness of all parties to work in the collective interest. This approach allows for adaptation as matters resolve themselves over time.

Lyons et al. (2019) coined the term 'mobility intermediary' to distinguish between the operators of transport services and the providers of mobility information and ticketing. They stressed the imperative for a public transport agency to regulate and oversee the MaaS portal. They also stressed the behavioural dynamics needed to facilitate a mass adoption of MaaS, flagging a strong potential market among youth who have yet to become car-dependent.

Operations

In terms of analytical tools, Gould (2018) examined the technical modelling of future MaaS scenarios to allow cities to plan for the development of MaaS. In discussing the suite of software available, Gould asserted that it should afford planners the opportunity to simulate operational scenarios to optimise traffic patterns and system uptake by configuring levers such as:

- vehicle characteristics and dynamics
- drop off, pick-up and interchange points
- network-wide traffic control
- connected vehicles and infrastructure
- interactions between various modes of transportation, including AVs, pedestrians and bicycles.

The software also allows for the substitution of privately owned cars with MaaS services to demonstrate how higher system utilisation can be achieved to obtain a lesser environmental footprint than in car-oriented cities.

Payment approaches are another operational matter to consider. Ho et al. (2018) examined the appeal of MaaS to potential users in Sydney under differing payment scenarios: a subscription-based model (temporal coverage) and a 'pay as you go' model. Using a stated-preference technique, they found that half of those surveyed found MaaS offerings to be appealing, although there was significant variability among the sample. Infrequent car users being the most likely adopters, and car non-users the least. The findings suggest that the rollout of MaaS should be carefully segmented, with different groups and modes cross-subsidising others to obtain the most commercially viable rollout.

International practice

As MaaS is a nascent technology, tied in with emergent technology and also governance and regulatory issues, there is not yet a great deal of empirical material as to how the technology is being approached internationally. Policy statements are being made, but on-the-ground trials are relatively scant. This is in contrast with other areas of technological innovation, such as ride-hailing, where there are plenty of documented case studies about how the entry of the mode into the market has been dealt with at a governance level.

Finland, one of the nations behind the development of mobile phone technologies, has also been at the forefront of MaaS. Hietanen (2014), originally from the government body ITS Finland, has gone on to found MaaS Global, billed as 'the world's first ever mobility operator'. Heikkilä (2014) noted that the City of Helsinki was not at that date ready to knit together the differing aspects of MaaS.

Weckström et al. (2018) observed that Helsinki is now at the forefront of MaaS development yet state that while the early MaaS trials in Helsinki were discontinued for budgetary constraints, other reasons may have played a part.

First, scant attention was paid to who the end-user target groups were. The planning of services failed to account for different user groups, ranging from the car-dependent to the socially disadvantaged. Furthermore, initial analysis into spatial and temporal patterns by socio-demographic group could have produced a more optimum tailored package of services (including schedules and routing).

Second, much greater emphasis could have been placed on marketing and public education regarding the MaaS service, with different techniques used for different groups.

Third, the MaaS platform itself could have been more integrated and user-friendly, allowing for both booking and route timetables, with the services integrated into the public transport fare system as well as enabling post-service options.

Some MaaS services have focussed on an open platform model. For example, MaaS Global (2020) is a private firm offering the WHIM app but is anti-monopolistic with the service layer and the production layer separated—which means that the operator of a transport service cannot own or regulate the app itself. Whim is being trialled in four European cities (Helsinki, Birmingham, Antwerp, Vienna) and is about to be launched in Singapore. Whim subscribers in Birmingham can pay £99 a month for unlimited travel on public transport, or £349 for unlimited use of public transport, taxis, bikes and car hire, with the company currently looking to sign up their first 500 users.

Elsewhere in Scandinavia, Karlsson et al. (2016) reported findings of a MaaS trial in Gothenburg. The trial, UbiGo, was developed as an aspect of the Go:Smart project and enrolled 195 people from 83 houses. They found that the trials were positive: participants were more positive with the MaaS trial than with their previous travel option. There was user satisfaction with the modal 'smorgasbord', which was not only conceptually simple but also improved access and flexibility, convenience, and economy. On the governance aspects of the trial, they identified the need for collaboration and cooperation between the operators and the state to foster interconnectivity. This not only includes services but infrastructure, information and payment—potential areas of conflict between the public sector and private sector operators. The evaluation of UbiGo indicates that the main obstacles to further dissemination of MaaS are likely to be at a commercial level between competing entities, and that the state has a crucial role to play in regulating this.

3.1.2 Ride-hailing apps and car-sharing

Summary

Ride-hailing involves digital platform-coordinated taxi services that are typically sourced from individual drivers and vehicles, usually via a smartphone application that incorporates trip requests, user and vehicle location and payment components. Ride-hailing contrasts with traditional taxi services, which have typically been organised via cooperative, syndicated or centralised institutional mechanisms. Ride-hailing platforms typically rely on user feedback for service and quality control rather than regulation, which is the case for conventional taxis. Car-sharing platforms provide access to a geographically distributed (rather than centralised) pool of vehicles, which may be accessed on-demand via a smartphone app that incorporates vehicle location and payment.

Key issues for ride-hailing include:

- the potential for quasi-monopolistic control of the platform
- the avoidance of regulation and safety
- the degree to which services may be able to meet community service obligations in outer suburban and regional areas.

Key issues for car-sharing schemes typically relate to:

- integration within sustainable transport systems
- access to public road space for parking.

The geographic distribution of vehicles in car-sharing schemes indicates a dependence on relatively good public transport.

Domain discussion

In this section we consider ride-hailing services such as Uber or Didi, which involve the use of a digital mobile platform to source services similar to conventional taxis. With ride-hailing, the critical innovation is the mobile platform that mediates between the users and service providers incorporating trip cost estimation, vehicle summoning and payment systems, along with quality review. In contrast, car-sharing schemes provide digitally mediated access to a geographically distributed pool of shared vehicles, typically cars, which users may access on a combination of subscription and per-trip models.

Both ride-hailing and car-sharing schemes are viewed as substitutes for car ownership, although the extent to which this substitution occurs in practice is debatable. The key feature of both schemes is the platform itself, as it allows for a reduction in transaction costs in mediating between users and suppliers of services, such as between the drivers and their vehicles in the case of ride-hailing. However, there is debate over whether a service such as Uber is merely a platform or whether its role encompasses the suppliers as well—see for example Mudrić et al. (2020).

Disaggregating technological and socio-institutional developments in transport innovation into discrete components can be challenging. In this discussion we combine car-sharing platforms, such as GoGet and ZipCar, alongside ride-hailing platforms, such as Uber, Didi, Ola and others. Car-sharing may be seen as different from ride-hailing, as car schemes such as GoGet or ZipCar typically involve users driving themselves; they do not cater purely to short trips and thus do not directly compete with the taxi market or public transport, although vehicles in car-sharing schemes tend to be located in areas with good public transport accessibility. However, the use of a mobile portal or platform and the presence of UberPool or other shared-ride schemes suggests that they should be discussed in a similar context. This overlap is also pertinent when considering ancillary topics such as AVs, whose policy justification is usually predicated on the sharing of rides.

Shaheen et al. (2018) suggested that 'shared mobility' is an innovative transportation strategy that enables users to gain short-term access to transportation modes on an 'as-needed' basis rather than the shared mobility that arises from scheduled public transport services on fixed routes. They noted how the modal suite is broad, covering car-sharing, bike-sharing, ride-sharing, for-hire driver services, and micro transit (which is discussed in a later section). Kathan et al. (2016: 663) defined the 'sharing economy' as a 'rising pattern in consumption behaviour that is based on accessing and reusing products to utilise idle capacity'. They argue that the emergence of the sharing economy presents both significant potential and threat for emerging and incumbent entities; they raise the questions as to whether or not this is an ephemeral trend, and how the sharing economy will affect existing businesses.

Dowling and Kent (2015) focussed on car-sharing schemes such as GoGet and ZipCar and noted these modes of access are now becoming relatively mainstream with the option to utilise shared mobility assets being present in 1100 cities. Within a policy context, they note that the emergence of car-sharing has taken place against varied strands of academic currents:

- the examination of transport policy
- a greater involvement of the private sector in transport provision
- the need to change behaviour to use personal vehicles less
- the willingness of the state (in many cases) to allow market innovation.

However, the authors noted that car-sharing schemes have not been overly considered within the transport policy debate and suggest that a greater understanding of the motives for car-sharing can enrich the transport policy debate.

Governance

Ride-hailing platforms have been subjected to scrutiny because of their potential ability to exploit quasi-monopoly positions in urban markets via loopholes over their status as service providers. Dudley et al. (2017) took a somewhat punitive view of Uber, seeing it as an entity that has circumvented a lack of government regulation—or specific clarity around the regulations—to achieve competitive advantage. They suggested that the ease of the company's user-friendly platform has allowed for the disruption of the urban transport sector. They noted the political controversy generated by Uber, as well as the trade-off between governments and regulators to capitalise on disruptive technologies while regulating their impacts for the common good. London is shown as the case study by which the dynamics of the public dilemma to regulate Uber has unfolded, as the London transport regulator suspended the right of Uber to operate until it agreed to certain regulatory conditions.

A crucial issue when discussing ride-hailing (and also noted in the earlier MaaS section) is the separation between the transport operator and the provider of the app. Recent legal precedents in Australia established that the app providers and ride-hailing firms are not employers, but this may become a more pertinent issue when the ride-hailing firms consider whether or not to contract for service kilometres in low-density areas in the future.

Young (2019) suggested that it is still unclear whether or not the arrival of ride-hailing has affected congestion. In noting the relatively higher price of ride-hailing than transit, Young makes a case for the regulatory framework of the ride-hailing industry being similar to that of the taxi industry, so that ride-hailing is appropriately positioned against those that contribute to less individualised transport.

Operations

Ride-hailing apps such as Uber are widely considered to have circumvented existing market entry regulations, and thus disrupted the sector (Dudley et al. 2017). For example, Acquier et al. (2017) noted the complexities of the sharing economy, and used Uber as an example to discuss the potential role of state regulation of the informal sector. Acquier et al. noted the widespread view that Uber should not be classified as part of the sharing economy as it is market-oriented. Instead, Murillo et al. (2017) emphasised a seeming loss of government control over market entry regulations and technologies into established sectors, and ask whether the sharing economy amplifies the worst excesses of a dominant market model. Harding et al. (2016) approached the discussion from

the perspective of the established taxi industry. They examined how smartphone applications have changed global taxi markets and their regulations, and concluded that governments should seek to address the potential monopolistic potential of an app-led taxi market.

Concerns have been raised about the impact of ride-hailing on public transport demand and route sustainability (Hensher 2017; Nelson and Sadowsky 2019). Nelson and Sadowsky (2019) observed that market entry for ride-hailing companies Uber and Lyft took place gradually, and that public transport usage at first rose with the arrival of the first platform, but then fell after the introduction of the second. This trend varies depending on the public transport region and mode.

Henao and Marshall (2018) examined whether or not the rise of firms such as Uber and Lyft has reduced driving overall, and concluded that there is scant research on the topic. In a study of Denver, they assessed the impacts of ride-hailing on overall city vehicle occupancy, modal shift, and vehicle distances travelled. They did not seek data from Uber or Lyft but constructed a synthetic dataset by one of the authors driving for both firms for a total of 416 trips. The authors estimated that ride-hailing leads to significantly more vehicle miles on the road than would otherwise have been the case. In a further study Henao and Marshall (2019) examined the impact of ride-hailing on parking, including overall demand and as a deterrent to driving. The results suggest that ride-hailing, as it replaces personalised car trips, could reduce parking demand at facilities such as airports, events, bars and restaurants. However, the authors also suggested that ride-hailing may be increasing the overall volume of car miles, and they conclude that parking stress is a major reason to deter a person from taking a trip.

Hall and Krueger (2018) examined the driver pool that Uber draws from, finding that drivers are drawn to Uber's platform for reasons of remuneration complexity, and the lack of a disjoint between hourly earnings and hours worked. Unlike the taxi industry generally, it appears that Uber drivers are sourced from both younger and better-educated market segments, with many drivers holding other jobs when they begin driving for Uber and continuing these jobs afterwards. It is this degree of labour market involvement and a need for flexibility to smooth income fluctuations that attracts the drivers to use Uber. With labour costs being a considerable part of a ride-hailing firm's cost base, a large-scale rollout of AVs is likely to have ramifications for the sustainability of ride-hailing businesses that use human drivers, but significant potential profits for those that can access driverless vehicles to provide their taxi services.

International practice

Variations in international practices of car-sharing and ride-hailing are described and discussed in the literature. Car-sharing can be driven by the market, as is the case of Réseau Citiz—a car-sharing operators' cooperative across France. They can also be an adjunct to state transport operations; for example, Deutsche Bahn's Flinkster offers standalone plans, or discounted add-ons to rail season tickets to those who wish to access its car-sharing scheme.

Differing approaches to the regulation of ride-hailing firms have occurred between cities and countries. Sun et al. (2019) noted that in the early stages of development across the world, ride-hailing was generally seen as disrupting the traditional urban transport regulatory frameworks. Sun et al. described four ways that cities internationally have regulated ride-hailing:

- Singapore established a register records system to manage ride-hailing, without setting an entry threshold.
- California created a regulatory middle ground, allowing ride-hailing to operate with government regulatory oversight.
- London classified ride-hailing services under the private hire vehicles regulation system and set up a lower entry threshold—however, London has since tightly regulated Uber.
- France saw Uber as a traditional taxi operation subject to orthodox taxi regulation, which prevented the firm from entering the market.

Sun et al. (2019) showed London as the case study through which the dynamics of attempts to regulate Uber have unfolded. In November 2019 Uber's licence was revoked in London for a second time. The company's license was reinstated via a late-2020 court decision, though time limited and conditional.

Many American cities are considering—or in the process of—regulating companies such as Uber and Lyft, yet regulation has not been well documented across jurisdictions, which is handicapping the coordination of a universal national approach (Beer et al. 2017). The key issues discussed by Beer et al. (2017) include:

- an obligation to share trip data with municipal planners
- driver checks
- the right of a firm to operate in the marketplace.

The effects of ride-sharing have also been debated in Canada. Zwick (in Zwick and Spicer 2018) argues that Uber exploits legal loopholes (see earlier discussion) or enforcement deficiencies in provincial and municipal laws. This results in avoidance of health and safety standards, degradation of employment standards and increased automobile use in urban centres.

By contrast, Spicer (in Zwick and Spicer 2018) argued that Uber:

- injects competition into formerly uncompetitive 'broken' markets in usefully disruptive ways
- offers affordability for users, thus generating a consumer surplus
- creates new employment opportunities for drivers
- provides for the health and safety of drivers and users.

In commenting on this debate between Zwick and Spicer, Young (2019) took issue with Zwick's concerns about safety, suggesting that the driver-owner ride-hailing model may incentivise drivers to maintain their vehicles to a higher standard than conventional pooled taxis. Young (2019) also suggested that ride-hailing is breaking the nexus between automobile ownership and urban access for younger cohorts, resulting in greater perceived convenience for users. Zwick's suggestion that ride-hailing will make congestion worse is considered premature by Young (2019). In contrast, Young (2019) takes issue with Spicer's claims that ride-hailing is an affordable mode of transportation, as it is considerably more expensive than public transport—a problem exacerbated by the need to have a credit card when using apps, a financial instrument that many households lack. Young (2019) also raised concerns about the evidence for ride-hailing providing employment opportunities, suggesting that effective wages are very low. In turn, Young suggests that while ride-hailing should be legalised in Canadian cities, authorities should focus on the overall social costs and consider strict regulations similar to those imposed on the conventional taxi sector.

The experience in China has been more complex than other jurisdictions because of the relatively strong and controlling government apparatus (Zhu et al. 2018), as well as ruthless competition between operators. This has resulted in conflicts between the emerging economic paradigm and an older public administration system that fails to separate service provision and overall systemic control (the purchaser–provider divide). Zhu et al. 2018 offered a case study of Didi Chuxing—China's largest online ride-hailing firm—as an example of enterprise and bottom-up innovation. Sun et al. (2019) described China's regulation of ride-hailing as having gone from an initial laissez-faire framework to strict regulation. There is still a lack of clarity about whether regulation should take place at the national or local level.

In summary, ride-hailing apps have dispersed across the globe rapidly, and spurred vigorous scholarly and policy debates about:

- their appropriateness as a mode of access to transport
- the business model through which they operate
- their effect on transport networks.

Initially, the digital platform on which ride-hailing is premised was 'invisible' to regulators and thus able to disperse rapidly within given jurisdictions, but policy and regulatory agencies subsequently moved to regulate ride-hailing through various mechanisms. In many jurisdictions ride-hailing has been subjected to regulatory regimes that approximate that of the conventional taxi sector. Thus, ride-hailing offers a useful case study of disruptive innovation generating a regulatory response.

3.1.3 Micro-electric mobility

Summary

Micro-electric mobility involves electric motorisation of small mobility vehicles, such as scooters or bicycles. Access to micro-mobility has also been offered via a platform shared service in some cities.

For micro-mobility, there are issues of definition leading to uncertainty and variation in licensing and regulation, and there is interest in the extent to which these modes are integrated with other modes in a MaaS platform.

Domain discussion

Micro-electric mobility involves electric motorisation of small-scale previously active personal transport modes such as bicycles and scooters, and small internal combustion engine (ICE) powered two-wheeled vehicles ('mopeds', scooters and small motorbikes). Power-assisted electric bicycles (e-bikes) have been available since the late-1980s, when they emerged in Japan as an option for elderly cyclists (Parker 2002). Their use has expanded over subsequent decades in Asia and Europe, where they have considerably displaced conventional ICE-drive trains in power-assisted bicycles. Global distribution has been uneven. However, the availability of cheap high-capacity battery technology has allowed their rollout at affordable prices over the past half-decade. The uptake of e-bikes has recently been followed by the emergence of electric scooters, which serve similar markets although at differing scales. Micro-electric mobility has also entered the freight market through last-mile delivery services, where small vehicles have cost and access advantages over conventional freight vehicles such as vans (Nocerino et al. 2016).

Micro-electric mobility has been debated in the literature. Many authors consider e-bikes to be a sustainable alternative to automobile usage (Apostolou and Reinders 2018; Parker 2002; Rose 2012). They see e-bikes as offering all the benefits of conventional cycles, as well as being capable of faster and longer trips, with more comfort and less effort for the user. In particular, Apostolou and Reinders (2018) focussed on what they deem an environmentally sustainable form of e-bike, the 'solar-powered e-bike', which in their view represents an expansion of the existing literature examining solar power in transport.

However, the merits of e-bikes have been debated, including the extent to which they displace physical activity by existing conventional cyclists or motivate non-cyclists to take up the mode. Sundfør and Fyhri (2017) investigated this issue through a survey of 300 participants and showed that people who already cycled a great deal showed considerably less interest in acquiring an e-bike. The study concluded that there was little change in activity as a consequence of purchasing an e-bike, as the appeal of the mode is strongest for those who are already physically active. Conversely, interest in e-bikes was greatest among those who were not already regular cyclists. The authors concluded that wider uptake of e-bikes would not displace physical activity, thus raising little concern from a public health perspective. Apostolou and Reinders (2018) also drew on results of a Dutch National Travel survey into the users of e-bikes, which showed that the main group of users are affluent commuters between 40 and 60 years of age who travel longer than six kilometres each way for their daily commute.

Concerns have also been raised about the safety aspects of e-bikes. Hertach et al. (2018) noted a high risk of single-vehicle crash incidence associated with e-bikes in Switzerland, with 17 per cent of a sample of over 3500 e-cyclist survey respondents having had a crash in recent years. As may be expected, the incidence of single-vehicle crashes increased with the distance that the mode was used. It was especially high among males using the mode as a commuting vehicle—either to work or to school. People who were older and less fit than others of comparable age were also prone to accidents. They concluded that education and infrastructure improvements to cater to e-bikes should be used as remedial policy measures (Hertach et al. 2018).

In addition to the general market uptake of e-bikes, powered two wheelers (or e-scooters) have recently been adopted in many cities. Perspectives on e-scooters are mixed, in part because their low small scale means they can be easily ridden on footpaths and thus may conflict with pedestrians, yet their slow speeds mean they are viewed as too vulnerable to operate in general traffic.

Yet e-scooters do provide an alternative mobility option to walking or cycling. In a study of e-scooter use in Munich, Hardt and Bogenberger (2019) proposed that e-scooters, because of their ease of charging and modest dimensions, can make a considerable contribution to easing transport problems because of their low emissions, lower traffic road space requirements and modest parking needs. They showed that, within Munich, a significant volume of daily trips was doable by e-scooter, although concerns were raised over safety, baggage-carrying capacity and exposure to adverse weather conditions.

The safety of e-scooters has been a prominent feature of discussions about their impacts (Fishman and Cherry 2016). In many cities, pedestrians have been increasingly sharing footpath space with dockless shared e-scooters. This introduction of e-scooters has received pushback from pedestrians. Complaints reported in the media include illegally parked e-scooters blocking walkways and footpaths, as well as safety concerns from pedestrians who do not feel safe around moving e-scooters. However, little is known beyond a few initial studies on e-scooter parking and anecdotes about pedestrian perceptions of e-scooter safety. James et al. (2019) conducted a survey of 181 e-scooter riders and non-riders, asking about their perceived safety around riders of e-scooters and experiences on footpaths. Divergent perspectives regarding safety between riders and non-riders were found. James et al. (2019) reported that their survey showed that e-scooter trips displaced trips otherwise taken by ride-hail services or taxis (39%), on foot (33%), bicycle (12%), bus (7%), or by car (7%).

International practice

E-scooters have been available as individually owned modes for just under a decade, but mass-utilised scooter-sharing schemes have only been operational in the field for around two years. The same is true of e-bikes, which have been available as an individually owned mode for over 10 years; since 2007, e-bikes make up around 20 per cent of all the vehicles on the streets of the major Chinese cities. Regular cycle-sharing schemes have also been in operation in cities for a lengthy period, but shared *e-bike* schemes are only recently beginning to emerge—for example, the Uber Jump rollout undertaken in Melbourne in March 2020.

Micro-mobility may be considered 'disruptive' as it offers new modes or variants of modes used in ways that are different to (or intersect with) conventional modes. Consequently, policy responses to the way these modes are regulated has varied. The major regulatory issue with e-bikes relates to their classification, which depends on the degree of power that a motor can deliver, and when this power is applied in conjunction with pedalling.

Broadly there are four categories:

- pedelecs—which are pedal assisted with a relatively low top speed
- s-pedelecs—where the top speed is faster than a pedelec and can be sustained without pedalling
- power on-demand pedal assist—where there is an option to use either mode of propulsion
- power on-demand only.

The model of e-bike deployed dictates whether or not it is classified as a cycle, a moped or a motorcycle. This in turn dictates if:

- a licence is needed
- there is a minimum age for riders
- the roadway can be accessed using the mode.

Approaches vary across jurisdictions.

Classification for e-scooters can range from motorised and requiring licensing and registration, (as in Singapore), to a far softer approach where they are classified in the same way as bicycles (as in Austria). There are different approaches to protective equipment such as helmets, and the place in the carriageway where they may ride: on the road, in a cycle lane, or on the footpath. In Singapore, e-scooters may not be taken onto public roads. The scooters are accessed via an app, which shows a user the location of a scooter; once the scooter is hired, its wheels unlock and it can be used. At the end of the trip, the user locks the scooter again, locking the wheels. Scooters are fitted with alarms and tracking devices to prevent theft.

In Belgium, e-scooters are allowed onto public roads but they are limited by an upper speed limit of 25 km per hour; moreover, protective gear is not a legal requirement. Another issue is insurance. For example, in Ireland it is not possible to insure e-scooters, and until recent regulations were passed, this led to their seizure by the police if they were taken on the road.

In many cities, e-bikes are available via public rental platforms mediated via smartphone apps. These systems operate in a similar way to car-sharing by combining GPS search and tracking, and payment systems. Similar public e-scooters or scooter-sharing schemes are becoming available globally through companies such as Bird. Bird operates over 100 schemes across the globe. Lime is operating in Brisbane. Lyft and Uber have also implemented scooter-sharing schemes. Consolidation has taken place in the global industry—for example in 2018 Uber acquired a minority stake in a local firm Grab to enter the Asian market.

Lime is headquartered in Singapore and provides scooter-sharing systems to more than 50 cities in Europe, including Berlin, Paris, Rome and Madrid. In January 2018, e-bike provider Jump was established in San Francisco by ride-hailing company Uber as a dockless e-bike system. Jump and similar schemes have been introduced to other cities globally. Melbourne, for example, saw the introduction of Jump dockless e-bikes in February 2020.

In some jurisdictions, electric micro-mobility systems are being integrated with MaaS. For example, in Berlin the Jelbi platform allows e-scooter short-term rental that is integrated with U-Bahn, trams, electric cycles and car-sharing schemes. Users can reserve combinations of modes in a single trip and payment. Jelbi requires all service providers to be fully integrated into an app.

3.1.4 Autonomous vehicles

Summary

Automatic operation of urban railways, albeit with a driver present in the cab, was introduced on the London Underground in 1967, with the opening of the Victoria Line. Fully automated driverless urban railways now operate in 42 cities around the world. Australia's first driverless train began operating in Sydney in 2019, and implementation of this technology has been proposed for Melbourne with the opening of the Melbourne Metro in 2025. Driverless trains are said to improve efficiency, reliability and safety. Similar benefits have been advocated for driverless cars and road freight—although the technology is in its infancy. In Australia, most of the innovation focus has been on automating the private car fleet.

Autonomous vehicles (AVs) (or driverless vehicles) rely on advanced sensor and information technology to undertake navigation and control of the vehicle during travel. AVs have been subject to much speculation in recent years, as various automotive manufacturers compete to deliver a viable AV to market.

AVs remain subject to considerable uncertainty regarding:

- their technological viability
- their operation within urban transport systems
- their effects on travel behaviour
- the institutional arrangements that should accompany their adoption.

There are mixed views about the benefits and drawbacks of AVs for car dependency, increased distances travelled, urban expansion, reduced mass public transport use, as well as their compatibility with complex urban environments with high levels of pedestrian activity. The timing of AV availability and rollout remains unclear.

Domain discussion

AVs are vehicles where a human driver has been partly or wholly replaced by digital systems that manage part or all of the driving task, including route selection and manoeuvring. While driverless operation of mass transit, such as trains and aeroplanes, has been commercially operational for several decades, the focus in recent times has been on the potential for automation of personal road transport (cars) and freight. Thus the term AV tends to be used to refer to a car. AVs have been the subject of extensive research and development over the past decade with major technology companies such as Alphabet, Apple and Tesla, as well as conventional automotive companies such as Volkswagen, Daimler and Toyota, expending considerable sums on such efforts.

AVs are subject to considerable debate regarding their viability, application and rollout, and their effects on transport systems (Shladover 2018). There have also been queries about the likely regulatory environment that will need to accompany their introduction, given the ambiguities posed about legal responsibility and liability because of the absence of a human driver.

Automotive engineers categorise vehicular autonomy at six levels, ranging from Level 0, with nil automated features, to Level 5, in which the vehicle has full driving automation (Society of Automotive Engineers 2018). At present there are few instances of Level 5 AVs operating in a similar way to a conventional human-driven vehicle on public roads in any jurisdiction. However, Waymo has been testing autonomous ride-hailing in Phoenix, Arizona, while Tesla has enabled an 'autopilot' Level 2 setting on some of its consumer EVs. Even if Level 5 AVs are not yet widespread, automotive manufacturers are already including lower-level technologies into new vehicles, such as lane monitoring and automatic collision prevention.

From an innovation perspective, AVs are considered likely to be disruptive because of the break they imply between vehicle operation and the occupants. For some, the assumption that automated technology will eliminate the safety risks of fallible human drivers is an important motivator in supporting AV uptake. Claybrook and Kildare (2018) argued that AV technology has the potential to reduce the number of deaths on public roads, but caution that proper safeguards must be established by federal regulators to govern the testing and deployment of AVs and ensure public safety. The imperative to develop AVs must not compromise public safety, they argue. They noted that two-thirds of respondents in an opinion poll they cited felt uncomfortable about sharing the road with driverless vehicles, and this would affect the popularity of the technology. Similar themes have been explored by Barabás et al. (2017), who argued that with increasing automation, drivers will have a smaller role to play when driving a vehicle, culminating in a point where they do not need to drive at all. However, they caution of the need for vehicles to make extremely fast decisions in diverse situations, which can involve moral trade-offs, and that at the current stage of research and development it is unclear how self-driving technologies will be able to handle extreme and unexpected events. They noted that the few available traffic crash test results have not yet been sufficiently scientifically verified, which indicates uncertainty about this issue. They also point to the issue of regulation keeping pace with technological development.

In a similar vein, the question of how the public interest is programmed into AVs has also been raised. For example, which will take precedence: the self-interest of the AV occupants, or the wider public good (Bonnefon et al. 2016)? This question is no simple philosophical exercise. In theory, AVs should reduce traffic accidents, but they may sometimes have to choose between two negative outcomes, such as running over pedestrians or sacrificing themselves and their passengers to save the pedestrians. In a series of surveys, Bonnefon et al. (2016) found that even though participants approve of AVs that might sacrifice passengers to save others, respondents would prefer not to ride in such vehicles. In addition, respondents would also not approve regulations mandating self-sacrifice, and such regulations would make them less willing to buy an AV. Such findings raise serious policy and practice questions.

Despite this, some insights into AV safety have been gained from trials. Dixit et al. (2016) noted the scepticism surrounding AVs and their ability to improve safety and the driving experience. They reported a series of Californian trials that reveal what happens when automated driving fails, or is limited: the autonomous mode disengages, and the drivers are expected to resume manual driving. In these cases, the number of accidents observed had a significantly high correlation with the autonomous miles travelled. Meanwhile, the reaction time to take control of the AV in the event of a disengagement had a stable distribution across different companies at 0.83 seconds on average. Lack of trust caused by the exposure to automated disengagements was found to increase the likelihood to take manual control of the vehicle. Others suggest that AVs have potential to reduce general traffic externalities. Martínez-Díaz and Soriguera (2018) argued that autonomous driving will reduce both accidents and congestion. Patella et al. (2019) presented the results of their noise emission modelling study of AVs, which suggests that AVs have positive effects in lessening noise pollution under a future hypothetical scenario of 100 per cent AV penetration of vehicle fleets compared to current traffic patterns.

Many authors have noted the potential for AVs to alter mobility practices (Gavanas 2019) and thus influence urban development patterns, location choices, land-use organisation and infrastructure design. This implies, suggested Gavanas (2019), that urban planners should consider the possible impacts from AVs on cities, and the future challenges for urban planning. A study of potential scenarios relating to the impacts of AVs on cities in Europe (based mainly on AVs for both passenger and freight distribution) showed significant positive outcomes in terms of traffic reduction, access to cars for older people, and the reduction of space required for parking vehicles—thus improving the overall efficiency of the transport system (Alessandrini et al. 2015). However, such outcomes are predicated on key assumptions such as a large-scale shift to shared use of AVs, a considerable supposition even five years after their study.

There is also debate over the business models under which AVs might operate. Two alternative scenarios are possible:

- AVs are owned like conventional motor vehicles, typically by one household solely for their private travel needs.
- AVs are provided like a public ride-hailing service and respond on demand to user needs.

These two alternative models imply very different scales of production demand for AVs. Dia (2019) suggested that automated vehicles could considerably disrupt the business model of the automotive industry, which would result in fewer people owning cars and many more sharing instead. Thus, the extent to which users are prepared to share AVs is an important point of debate. The results of a stated-preference survey by Krueger et al. (2016) showed that service attributes including travel cost, travel time and waiting time may be critical determinants of the use of AVs, including the characteristics of users who are likely to adopt AV services and their willingness to pay for service attributes. The Krueger et al. (2016) results imply that the adoption of shared AVs may differ across cohorts, whereby younger individuals and individuals with multimodal travel patterns may be more likely to utilise the technology.

The role of government has risen as a theme in AV debates, both in terms of facilitating the rollout and uptake of AVs and in managing the operational and wider consequences of the technology. Isaac (2016) emphasised the pivotal role of government when regulating and setting policies to smooth the way to a potential AV future—this is challenging when the development of AVs is being driven by private sector technological innovation. The situation around 'bottom-up' market entry and sector shaping being driven by the shared economy makes government regulation and urban planning challenging (Guerra 2016; Legacy et al. 2019).

For some authors, such as González-González et al. (2020), the introduction of AVs is a virtual certainty. However, they recognised that the timing of their introduction is much less clear, as is the transition to full automation—with the role of governments particularly crucial. Gonzalez-Gonzalez et al. (2020) observed that many governments are already working to facilitate this shift by, for example, amending and refining regulations to support the introduction of AVs, or supporting tests in different urban environments.

Meanwhile, urban and regional planners and decision-makers are still grappling with the uncertainties of the possible impacts of AVs on land-use changes and location choices, particularly in relation to the space available for vehicles, both:

- moving—i.e. road space
- stationary—i.e. parking space.

The uncertainty around the future technological viability and uptake of AVs has spurred calls for more research into this area of technical development and policy. Cohen et al. (2018) identified four main issues with the current research into AVs.

First, Cohen et al. argue, there is a strong focus among published research upon the more technical aspects of the subject, with much less attention given to social and behavioural issues. The subject of the potential impacts of AVs in general, they suggest, is researched, with very few topics studied in any depth and some, such as health impacts, barely acknowledged.

Second, while some researchers display a concern about the technology's potential for creating wider negative impacts, much of the literature appears positive about AVs, thus raising questions of optimism bias.

Third, they suggest there is relatively little empirical work on AVs in current operation and the user responses to them, with most writing on the subject being speculative in nature.

Fourth, the research overall is either not academically rigorous, or rather narrowly focussed, with authors tending not to consider a sufficiently wide range of possible futures in arriving at their conclusions, or focussing on a very specific aspect (Cohen et al. 2018). This may stem in part from the lack of interdisciplinary research in the literature, with most work coming from a single discipline—predominantly engineering or computer science. Clearly there is a need for greater clarity in this area of knowledge.

International practice

AVs are being trialled in many locations globally. The iMove Australia consortium documents 104 instances of AV trials (iMOVE Australia 2020). The iMove dataset is not exhaustive, with most of the identified trial programs occurring in European or North American countries. While the broader transportation literature pays increasing attention to AVs and their implications for cities, there is a relative dearth of studies reporting the outcomes of AV trials. This may be because many of the systems under development are being undertaken by private companies, which exercise a proprietary control over the dissemination of the results of their trials. Perhaps the most advanced trial of autonomous vehicles currently reported in the research and grey literature is that of Waymo, a Google Alphabet company undertaking road trials of AVs in Phoenix, Arizona. From the reports that have been made publicly available, the Waymo trial taxis appear to be functioning autonomously in a real on-road situation, including conveying passengers. The Tesla electric vehicle company is a further innovator in the development of AVs. Tesla includes autonomous features within some of its existing vehicle product line, including a feature known as autopilot that can control some of the operation of a vehicle under normal driving conditions, albeit not at full autonomy, involving a degree of remaining driver control. Tesla is also undertaking trials of its AVs in a higher-level mode; however, these trials have been marred by incidents—including a pedestrian fatality.

A feature of the international experience is that many companies are characterising themselves as mobility companies rather than just automobile companies. This appears to signal that their approach to AVs may not be simply a replication of existing patterns of motor vehicle ownership but may involve alternative business models, whereby vehicles are pooled to be accessible on demand by passengers. How business models evolve internationally deserves to be the subject of attention by researchers and policy-makers.

3.2 Innovation domain: Influencing travel behaviour

Many innovations seek to influence travel behaviour, typically to reduce reliance on private cars. This includes explicit behavioural modification programs, such as TravelSmart, or may involve wider policy frames that reduce the convenience or raise the cost of car use relative to other modes. There has been considerable debate about the relative merits of alternative approaches to travel behaviour change, ranging from individualistic explanations and strategies to modify behaviour to other approaches that make alternatives more attractive. Institutional approaches to service provision, such as the design and operation of public transport agencies, has also been included as foundations for travel behaviour change away from the car.

As with other institutional innovations, particular strategies and policies may be applied in some jurisdictions but not in others. As a highly car-dependent nation, Australia has perhaps pursued innovations to influence travel behaviour with less vigour than others where rates of car use are lower. There remain many policy opportunities to influence travel behaviour away from cars, whether in Australia or elsewhere. However, most of these are institutionally oriented.

3.2.1 Reducing car dependence

Summary

The need to reduce the share of travel by automobiles is a recognised policy concern in Australian metropolitan plans (for example, DELWP 2017). Innovation in this context arises from the application of measures to influence behaviour at individual and system levels.

The understanding of factors underpinning car dependence relative to other modes is a well-established domain. Broadly, cars are understood to offer a more convenient option that is artificially under-priced relative to other modes. However, there is a body of literature that recognises that car use is determined by institutional, environmental design, as well as individual factors. Despite recognition of the adverse consequences of high levels of car dependence, Australian governments remain hesitant to impose disincentives to use cars. Systematic measures to support mode-shift away from automobiles would comprise innovation in the Australian context.

Domain discussion

Although the car has provided a high level of personal mobility for urban residents, high levels of dependence are widely considered to impose negative consequences for cities. These consequences include:

- direct costs of car operation and use
- safety costs from vehicle crashes and injuries
- health costs from pollution
- noise
- foregone physical activity
- heightened stress while driving.

There are also the fiscal costs of providing infrastructure to accommodate expanding traffic volumes.

While the car may have been viewed as innovative when it first appeared, and subject to continuous technological innovation as a machine, it is actually one of the oldest forms of mechanised transport. However the regime of automobility (Geels 2002; Urry 2004) that encompasses the car is now viewed as trapped by a path dependence (Curtis and Low 2012; Low and Astle 2009) that limits potential for a transition to a more sustainable mix of urban mobility modes. Given entrenched car dependence in many cities, efforts to reduce reliance on automobiles for urban travel may now be considered innovations. Many jurisdictions in recent decades have instigated policies to reduce automobile dependence across such domains as urban structure and urban form, as well as infrastructure

provision and regulation. There is an extensive literature on these topics, ranging from very micro-scale aspects of travel behaviour and policy design to metropolitan-scale debates about transport and land-use strategy and policy.

Some policies and programs have sought to reduce car use through behavioural interventions. One of the largest such efforts was the TravelSmart program that operated in major Australian cities during the late-1990s and 2000s. The program sought to modify travel behaviour through direct consultations with households, providing guidance and information about car use and sustainable alternatives. At the time, TravelSmart was considered a major innovation in the management of urban car use. While the program involved large numbers of households in many cities, the longer-run results were often ambivalent; a small proportion of households altered their travel behaviour away from the car, but there wasn't an accompanying gain in sustainable travel (Richardson 2005). James (2017) suggests that in its largest scale application in the City of Darebin in Victoria, the program was unable to identify changes in travel behaviour. Similar failures in Queensland point to the overall demise of the program. More critical assessments have argued that the premises of the scheme were flawed, and that the evaluation methodology contained biases that limited its validity (Morton and Mees 2010). The TravelSmart experience suggests that efforts to reduce car dependence that focus on behaviour alone and do not consider the overall 'regime' of automobility are unlikely to be successful.

Despite the TravelSmart experience, behavioural modification programs remain of wider interest to policy-makers and researchers. Baudains et al. (2002) assessed workplace intervention schemes to reduce car dependency by increasing the use of alternatives to the single occupant vehicle. The study, based in Perth, focussed on the policy objectives of reducing vehicle emissions and traffic congestion. Three intervention types were deployed:

- the degree of employee involvement
- environmental leadership and education
- information distribution and dissemination.

Behavioural change was noted in all three programs, but the third intervention relating to information sharing achieved the strongest impact. Eriksson et al. (2008) reported a pilot intervention program for heavy car users who were keen to use their vehicles less. Seventy-one car users were recruited to either an experimental group or a control group. All participants reported their car habit strength and motivation to drive less. After the intervention, it was seen that the intervention had made the choice of travel mode more deliberate, as the link between car use and habit strength was lessened. This suggests that strong habitual car users may be more suitable for interventions than those with a weak car habit.

Some research has focussed on the potential for travel behaviour away from the car. Anable (2005) examined the potential in the UK to mode-switch from the car by identifying six distinct psychological groups from an attitudinal survey, each with differing degrees of mode-switching potential. Anable (2005) found that socio-demographic factors had little bearing on travel profiles of the segments, suggesting that attitudes largely cut across personal characteristics. Instead, Anable suggested that lifestyle characteristics may serve to better identify attitudes to car use that could be used in designing targeted hard and 'soft' transport policies.

Lifestyle links to car dependence have been identified in Australia, particularly concerning active transport usage and health. Merom et al. (2018) assessed a variety of socio-economic and demographic groups using the Sydney Greater Metropolitan Household Travel Survey (2000–June 2015), and found a relationship between health and physical inactivity. The findings are relevant for informing specific policies that are aligned with public health and transport goals—reducing car dependency in favour of active travel can address the issues of prolonged sitting and physical inactivity.

Some studies have also considered 'barriers' to public transport use, although these are often located well beyond the individual and within the wider institutional system of transportation planning and management (Curtis and Low 2012). Buys et al. (2012) examined the barriers to public transport usage among older people and the model of car dependence among older Australians. The findings suggested that relative convenience, affordability and health/mobility may dictate transport mode choices, and that for this group, the car is considered more convenient for the majority of suburban trips, irrespective of the availability of public transport. Buys et al. (2012) recommended that information on local public transport should be provided to older groups that are ceasing driving, to help their transition away from the car.

Belton Chevallier et al. (2018) noted how low incomes and car dependency often accompany each other. However, the two characteristics can be independent, for although their capacity for mobility is lower, low-income households in outer suburbs remain mobile. An analysis of mobility adjustments by low-income households according to changes in their circumstances was undertaken, focussing on the French cities of Paris and Dijon. Low-income households continue to reside in car-dependent areas by reducing their trips and by using local resources and networks to lower the costs of their car dependency. The findings show that car dependency is difficult to shift, and that many households will still try to retain ownership of their vehicles even when their circumstances change.

International practice

Lessening car dependency through various measures is the largest policy imperative that runs through this report. As such, the case studies offered here cover initiatives to reduce car dependency—both ownership and usage. The policy solutions for reducing car dependency are detailed in other sections of this report.

Litman (2019) demonstrated how the setting and enforcement of vehicle miles travelled (VMT) reduction targets are crucial to tackling car dependency. The US policy requires state agencies to adopt this approach—for example, California has a target to reduce vehicle miles travelled about 15 per cent by 2050, compared with expected levels. Oregon and Washington and some other US cities have similar targets. In Oslo, Norway, a 2015 government policy decision sought no extra motorised vehicle kilometres generated in the city. A system-wide initiative saw the removal of car parking space, the blocking of through roads, an increase in cycle lanes and a significant widening of pavements into road space.

MaaS schemes in Helsinki and Berlin, car-sharing projects throughout France driven by the private sector, and a complementary offering such as a rail service (Deutsche Bahn) are ways to provide an alternative to car ownership.

The case of CrossRail in London and the MTR Corporation's building program in Hong Kong illustrate the need for car-restraining measures in tandem with innovative planning and financing structures.

3.2.2 Addressing declining public transport use

Summary

Declining public transport usage in some localities, particularly outer suburban and fringe areas, arises from a car-oriented planning approach and inadequate integration between transport goals and land-use regulations. The measurable levers of public transport elasticity and usage are well known, including:

- journey time
- wait time
- aversion to interchange (and more wait time)
- reliability and punctuality
- speed of travel.

Where public transport networks can cater to a very minor share of travel demand, travel by this mode may be seen as inferior to the car.

Good quality public-transport network planning can improve the quality of service experienced by users and, in turn, support patronage growth. Although there is wide variance internationally in terms of the quality of service provided by public transport, new approaches in a specific jurisdiction may be seen as innovation even if they are already part of normal operations elsewhere.

While Australian cities have implemented some elements of high quality public-transport network planning, there are many practices that are standard in other jurisdictions that would be considered innovative in the Australian urban transport context.

Domain discussion

In many jurisdictions, public transport is a subordinate mode to the private car in terms of share of urban travel. Scholars have debated the reasons for this difference. Some have pointed to factors that determine public transport patronage, relative to the car, such as urban form (McLeod et al. 2017; Mees 2000; Mees and Dodson 2011; Thompson 1977; Walker 2011). In this view, the relative density of population, as determined by dwelling density, determines the potential level of ridership of public transport. If a city is dispersed, then public transport cannot operate to high service levels and remain viable under prevailing arrangements for the financing of public transport. These authors prescribe increases in urban density as a solution, on the grounds that increased population densities will generate increased demand for public transport and thus make services more viable, to the extent that they can compete with the car for mode share. In this view, public-transport ridership is determined by urban form.

Another group of scholars has argued that while denser urban form is supportive of high levels of public transport patronage, the latter is independent of urban form. By this account, service quality—in terms of convenience of access to destinations via public transport networks—is the determining factor in the relative share of travel by this mode (McLeod et al. 2017; Mees 2000; Mees and Dodson 2011; Thompson 1977; Walker 2011). These observers argued that to improve public transport patronage, policies should focus on improving the quality of service provided, measured by variables such as:

- directness and speed of routes
- comfort
- safety and reliability of services
- convenient transfers among highly connected networks
- legibility of services in terms of wayfinding, maps and schedules.

Some argue that these principles of public-transport network planning are also applicable in low-density rural settings (P. Mees 2009; Petersen 2016).

Various innovations have been identified within the public-transport network-planning literature. For example, Mees (2000) argued that the *verkehrsverbund* model of state-led public-transport network management and coordination, as operates in some European cities (Buehler et al. 2019; Dunn 1980; Pucher and Kurth 1995), is a particularly effective means of providing a high quality network. While the model has been known in the literature since the late-1960s it has only relatively recently been recognised in policy discussions. The *verkehrsverbund* approach involves a centralised single agency that is responsible for growing public transport mode share by providing high quality multimodal networks that are able to compete with the car for urban travel. Although it can no longer be considered an innovation in the European context, in jurisdictions such as Australia it can be considered innovative. Since the mid-2000s, various jurisdictions in Australia have sought to reflect the *verkehrsverbund* approach to public transport management and operation, but these have only been partially effective—and institutions using the full European approach do not operate in Australia.

While the *verkehrsverbund* model of coordinated public-transport network planning has been expanding in Europe over the past few decades, the Anglophone world has tended to see contrary modes of public transport delivery based on franchising. This model typically involves subcontracting public transport operations out to private providers on the basis of detailed service parameters. It represents an evolution of such instruments since the deregulation of bus services was pursued in the UK in the late-1980s. The franchising model might be considered innovative, as it represents efforts to improve the value to the public sector from expenditure on the delivery of public transport. However, this question has been debated by researchers. For example, Mees (2005) argued that the incentives for profit-making through rent-seeking rather than patronage improvements are excessive and result in hidden cost to government. Sorenson and Longva (2011) suggested that privatised or franchised arrangements conflict with the coordination objectives of high quality public-transport networks, because of fragmented institutional structures, excessive competition and a focus on outputs rather than outcomes.

While the *verkehrsverbund* model has received considerable attention in the literature, there is a relatively modest body of knowledge on the application of innovative public transport network planning design *in practice*, with little systematic recording. McLeod et al. (2017) discussed the 'blockers and enablers' of public-transport network reform, noting that these are highly variable. Marsden and Stead (2011) investigated the general role of 'policy transfer' in transport, noting that while this may be a mechanism through which to improve policy in a given jurisdiction by applying policy ideas developed elsewhere, this is often an unsystematic process with many variables shaping what and how an original policy is applied in a new setting. They argue in favour of innovation in transport research through a focus on the factors that underpin successful efforts at policy transfer generally.

International practice

Of the specific evaluations of network reorganisation, much of the reporting has been either through consultants (Walmer 2012) or via practice guidance (Mees et al. 2010; Nielsen et al. 2005). The review of public-transport network-planning principles by McLeod et al. (2017) noted the review of Houston's public transport network undertaken by Jarrett Walker and Associates in 2015. Imran and Mathews (2015) investigated the rollout of new services with the Auckland busway, finding that although the busway-based services exhibited some characteristics of good public-transport network planning, the wider degree of integration within the overall network was relatively weak, thus not achieving optimal design. There is clearly potential for further literature to be developed on the advantages of public transport network-planning improvements, whether organisational, networked or coordinative.

Australian examples

There have been some efforts at public-transport network-planning improvements in the Australian context. Mees and Dodson (2011) undertook a review of recent public-transport network-planning innovations in Australian cities, noting that while there was some evidence of new approaches being applied, it was patchy and episodic, with many deficiencies remaining. Mees and Dodson (2011) argued that there were many opportunities for improved network planning across Australian cities. Loader et al. (2015) investigated bus network improvements in Melbourne and found that enhancements to service levels were resulting in patronage gains via mode-shift from car travel—which is in line with international evidence—and that disadvantaged users were benefiting, in particular, through improved social and employment access. Loader et al. (2015) assessed a set of sub-regional bus network improvements in Melbourne's western suburbs. They found strong short-run patronage elasticity gains of 10 per cent from a cost-effective network design that increased service levels by 15 per cent. This was beyond expectations, based on experience reported in the international literature.

Stone (2011) reported on analysis of public transport organisations in Australia and German-speaking Europe. Stone noted that the problems with underperformance of Australian public transport systems appear to lie with the way they plan and organise services. In contrast, Stone notes the proliferation of the *verkehrsverbund* model in Swiss, Austrian and German jurisdictions. In comparing the performance of Sydney and Melbourne with four case studies from those European countries, Stone (2011) noted that the latter tend to establish 'alliances' between planners, regulators and operators. Consequently, systems are able to present a unified 'offer' to patrons. Stone (2011) argued in favour of Australian cities making incremental steps towards a more unified system, but admits that further work is needed to better understand the success factors behind the European model.

Some attempts have been made to undertake systematic reviews of public transport networks. In 2012, the Queensland Government's Translink public transport agency undertook a systematic review of Brisbane's bus networks, partly based on network-planning principles (Department of Transport and Main Roads [DTMR] 2013). However, this review occurred within a contemporaneous policy environment of public sector expenditure reduction, which saw the review interpreted among the public as service reduction rather than service improvement. Following public expressions of concern, responsibility for the review was handed to the Brisbane City Council, which operates the main bus fleet in Brisbane. The council subsequently rejected most of the network review, retaining only a few minor adjustments to existing routes. This experience demonstrates the challenges of implementing network-planning approaches that markedly restructure legacy networks within which service logics are based on accretions of ad-hoc decisions over long periods of time. In addition to innovation in network design, there is also a clear need for innovation in public engagement around public transport, so that network improvements occur through consultative collaborative processes rather than being the concoction of transit agencies.

In summary, there remain many opportunities for innovation in the provision of public transport in Australian cities that do not depend on technological innovations—rather, they would involve institutional innovation.

3.2.3 Encouraging telecommuting and online retailing

Summary

Telecommuting involves workers using information and communications technology (ICT) to avoid travelling to a workplace. With improvements to ICT over recent decades, telecommuting has been viewed as a potential mechanism for reducing vehicle kilometres travelled, as well as reducing road and public transport network congestion.

However, despite continuing technology improvements, telecommuting had not been observed as being adopted by large numbers of employees prior to the COVID-19 pandemic.

There is now substantial evidence that the COVID-19 experience resulted in large proportions of employees and employers experiencing telecommuting, with significant proportions keen to utilise it for a much greater proportion of work practices. While this 'experiment' may lead to sizeable changes in practice, the extent and durability of such shifts is difficult to predict. A shift to telecommuting aligns with core strategic policies for greater localisation —for example, 20-minute neighbourhoods—which in turn demand to be supported by a greater share of capital investment and regulatory focus on improving local area amenity for active transport.

Domain discussion

Telecommuting involves workers undertaking work activity at home via ICT, so that physical commuting to a work office is replaced with virtual mobility (Elldér 2020). From a transport innovation perspective, telecommuting is viewed as a means of reducing the number of trips on the transport system, particularly at peak hour. This would result in reduced road congestion, but may also see reductions in public transport patronage and potential increases in local neighbourhood travel. Reduced travel demand, particularly by car, could reduce transport emissions (Hook et al. 2020). There are also suggested benefits for households in achieving better balance between work and lifestyle (Noonan and Glass 2012). However, telecommuting is not an option for every job type, and is more feasible in occupational categories that do not require manual or in-person labour, or where electronic communications can substitute for direct contact. Extending the use of ICT to other daily activities could further reduce travel demand, as can be seen with online shopping, online education, and some leisure activities, such as switching from cinema patronage to a streaming service.

Telecommuting has been discussed in the literature, as ICT has improved since the early 1990s when internet-based work expanded (Mokhtarian 1991). Telecommuting may be considered an ongoing and evolving transport innovation, whereby improvements in ICT support new arrangements in work location and connectedness. Handy and Mokhtarian (1996b), for example, noted that the prospects for telecommuting depend on the nature of the work being undertaken, and the willingness and wishes of employees and employers to accept remote means of working. They recognised that not every business for which telecommuting might be feasible will prefer to have its

employees working in that arrangement. Similarly, not every employee who has the opportunity to telecommute will opt to do so either as part or all of their work activity. Handy and Mokhtarian (1996a) noted that telecommuting depends in large part on government policies to facilitate and encourage its take-up through education and incentives, by showcasing case studies and eliminating barriers. Writing in 1996, Handy and Mokhtarian were reasonably certain that telecommuting would increase, while recognising there is a great deal of uncertainty about the specific patterns that might be observed in the future.

Various studies have assessed the transport implications of telecommuting. Lachapelle et al. (2018) suggested that many of the transportation impacts are uncertain, as telecommuters may use this mode to shift their travel time rather than reduce travel necessarily. O'Keefe et al. (2016) assessed the impacts of telecommuting in Dublin, finding that 44 per cent of Dublin's population telecommute at least once per month, in contrast to the three per cent figure reported in the Irish Census. They argued that this discrepancy reflected inadequate questions in the Census. The authors estimated that if 20 per cent of the working population of Dublin telecommuted one day per year, 60,000 tonnes of carbon emissions would be avoided.

In a study of telecommuting in Sweden, Elldér (2017) reported that telework weakens the relationship between urban structure and travel. Based on regression models of travel survey data, Elldér argued that telework results in heterogeneous daily travel behaviour based on personal attributes rather than on home–work locational relationships. This behavioural heterogeneity was also reflected in the sustainability of telecommuting was further supported by Chakrabarti (2018), who found that people who telecommute at least four times per month were associated with higher rates of transit travel active transport trips, plus increased overall physical activity, although with higher annual levels of driving as well.

Hook et al. (2020) assessed the carbon emissions reduction potential of telecommuting, finding that across a large sample of studies, a clear majority found that telecommuting reduces energy use. However, they cautioned that calculations of 'average' energy savings from telecommuting are difficult because of inconsistency in methodological approach across the studies. They argued that energy savings are likely to be modest across the economy.

International practice

In Australia, the proportion of people telecommuting has not been large. Based on data from the HILDA Survey (Household, Income and Labour Dynamics in Australia) Wooden and Fok (2013) reported that only five per cent of workers could be classified as 'home-workers', defined as working from home the majority of time. Such a figure necessarily includes those who operate solely from home, so the total share of workers who telecommute is likely less than five per cent. Dockery and Bawa (2014), also using HILDA data, reported around 17 per cent of Australians work some of their hours from home—on average 7.7 hours per week. A more recent analysis in WA found the average home-working rate was 3.4 per cent of all employees, but with variation by occupation category—with administrative workers (6.3%), managers (5%) and professionals (4.8%) having greater proportions of home-workers compared to other occupation groups (Babb et al. 2018).

The COVID-19 lockdown has given some insights into the potential for a far greater increase in telecommuting, with up to one-third of employed workers telecommuting (after accounting for job losses) (Beck and Hensher 2020). Although forced, both employers and employees have now experienced the effects of telecommuting, and early discussions suggest that this may lead to greater numbers of people telecommuting for at least part of the working week. Given continuing limitations on conventional office-based working practices because of COVID-19, there may be opportunities to extend and expand telecommuting practices (Dalheim 2020) in conjunction with the 20-minute neighbourhood policies that form the core of metropolitan strategies such as *Plan Melbourne 2017–2050*.

3.3 Innovation domain: Urban structures

Urban structure and transport systems are intertwined through locational dynamics of land use and accessibility. In general, locations with intensive land uses tend to be served by high quality transport networks, including public transport. Some key phrases need defining:

- **Urban structure** refers to the differential distribution of land-use intensity and type across an urban area.
- **Accessibility** reflects the ease of access to that location.
- **Urban form** refers to the physical shape, type and scale of the buildings and infrastructure of a given locality or region.

Urban structure influences urban travel patterns through the locational differentiation of land uses and transport accessibility. An urban structure that requires longer commuting distances to access employment may be less efficient than one where commuting is shorter.

Various consequences arise from inefficient urban structure. The problem of labour market 'spatial mismatch' has been long understood, while issues of transport accessibility and disadvantage are also well known. Inefficient urban structures are also known to compromise urban productivity. Issues of inefficient urban structure have been well documented internationally, and are also known in Australia.

Various intentions have been identified that would redress inefficient urban structures through planning and wider policy. These include:

- supplying infrastructure
- modifying land-use regulations and labour laws
- making it easier to start businesses
- utilising tax incentives
- investing more state money in training skilled workers locally
- lessening state-based regulations to allow portability
- increasing local research and development hubs, capital grants
- investing in vocational training.

There have been longstanding debates in urban studies about the significance of urban structure to economic, environmental and social outcomes. For example, an urban structure that concentrates employment in centralised business districts accompanied by residential dispersion across a wider metropolitan area may result in poor accessibility outcomes for less advantaged households, especially where urban land prices allocate such households to outer metropolitan zones where house prices are often cheapest. There have also been extensive debates about the role that urban structure plays in urban productivity. Intentions to reshape urban structure are often features of metropolitan plans. Such initiatives may be considered innovative if they can effect a shift in the overall structure of a city towards a more desirable arrangement.

Debates about urban structure are often linked to questions of transport mode (Newman and Kenworthy 1999). Typically, urban structures in which land-use activities are dispersed are also highly car-dependent. Conversely, there is evidence that urban structures that include concentrated activity nodes, including strong CBDs served by rail, exhibit lower levels of car dependence.

New planning and policy approaches to managing and shaping urban structure may be considered innovative—although this innovation may be jurisdiction-specific. There is innovative potential in planning policy and regulation that is able to shape urban structure to achieve more efficient travel patterns. However, the slow pace of change to both urban form and urban structure means that such efforts may require long periods to have any effect (Dodson 2010).

3.3.1 High-value local activity centres to lessen commuting

Summary

In highly car-dependent urban contexts with high-capacity road networks, land-use activities tend to disperse, as the low cost of travel allows access to a greater extent of land market. However, extensive automobile dependence can impose various internal and external costs on both travellers and society.

Management of urban structure to achieve efficient coordination of residential, commercial and industrial land uses has long been a concern for urban planning. Efforts to manage urban structure often involve coordination of transport and land-use planning around key nodes within metropolitan areas, around which activities are focussed and to which efficient transport services (such as heavy rail) are provided.

Efforts to strengthen activity centres within large metropolitan areas may be considered innovative in relation to prevailing patterns. However, they face impediments such as:

- the complications associated with ongoing car-dependent travel
- the task of coordinating and regulating land-use activities
- the need for institutional and political support.

Domain discussion

Urban structure has been the subject of extensive debate within urban studies. The question of the role that concentrations of land-use activity can play in shaping travel mode and distances has been particularly prominent (Thomson 1977). The influence of urban structure on commuting has been a particular feature of this discussion (Cervero and Wu 1998; Giuliano and Small 1991; Helminen et al. 2012). These questions have been most prominent in North American and Australasian debates, where high levels of car dependence have been linked to dispersed urban form and structure (Newman and Kenworthy 1989; Mees 2000). However, the question of metropolitan sub-centres and effects on commuting have also been addressed in Europe (Vasanen 2012; Vega and Reynolds-Feighan 2008), Latin America (Aguilar and Hernandez 2016) and Asia (Chiu 2012; Lin et al. 2015; Yang et al. 2019). There have also been extensive debates about urban structure in some European contexts, where the expansion of proximate cities has led to regional urban structures of interconnected centres of activity, resulting in references to 'polycentric' urban regions.

However, the discussion here focusses on questions about sub-metropolitan urban structure, and efforts among planners and policy-makers to engender concentrated urban structures that reduce commuting distances and levels of automobile travel while encouraging sustainable travel modes.

Planning policies to encourage stronger concentrations of activities within dispersed metropolitan areas in order to reduce reliance on automobiles for urban travel may be considered innovative in the context of previous planning, which either permitted or encouraged activity dispersion and increased automobile reliance. Many jurisdictions have sought to use activity centres as a mechanism of urban management.

In 1999, Europe adopted the European Spatial Development Perspective (ESDP) as a mechanism for understanding socio-spatial polycentricity applied at various spatial scales including inter-regional, intra-regional and metropolitan levels (Davoudi 2003). The ESDP aimed to improve social and spatial cohesion, while supporting regional integration into the European and global markets. In this sense, the ESDP was normative, as it viewed integrated polycentrism as a prerequisite for the sustainable development of localities and regions (Davoudi 2003). In turn, the ESDP was expected to inform metropolitan level planning across European jurisdictions.

In Paris, Aguiléra and Voisin (2014) assessed the links between urban form and commuting patterns and the CO_2 emissions associated with them. They distinguished between city-centre oriented commuting and local (suburban) commuting. They noted that a high jobs-to-resident ratio tended to increase the proportion of jobs held by residents—that is, people try to live where they work, where possible. Unsurprisingly urban density and

compactness are associated with more sustainable travel behaviour among residents, but not among non-residents, who travel long distances to workplaces in an area. Aguiléra and Voisin (2014) concluded that the shape of the public transport system connecting the districts to the city centre is a significant determinant of the proportion of jobs held by residents. In some cases, the network did not allow non-residents—many of whom who did not live in central Paris—to access work in the neighbourhood unless they used a car. Such findings demonstrated the importance of integration of non-central activity centres with major public transport modes. Similar insights were gained by Vega and Reynolds-Feighan (2008), who determined that differences in modal choice between centrally oriented and sub-centre-oriented commuters could be explained by the relatively poor public transport connections to the sub-centre.

In North American cities, the question of sub-centres has been subject to considerable debate. The challenge of overcoming extensive dispersed urban residential and employment patterns has led some to suggest that such efforts are not worthwhile, or that dispersion is more efficient (Gordon et al. 1986). However, others have suggested that suburban sub-centres can accommodate metropolitan employment growth (McDonald and Prather 1994), particularly in strongly monocentric cities such as Chicago. Even in Los Angeles, which has been identified as an archetypal dispersed city, Giuliano and Small (1993) noted the employment significance of the central zone. However, for Los Angeles, Giuliano and Small (1993) suggested that a combination of short journey length and household locational decision-making may militate against policy manipulation of jobs–housing balance as a mechanism for improving commuting times and the efficiency of metropolitan spatial structure.

Yang et al. (2019) described how policies within Chinese cities over 5 million in population have promoted 'municipal sub-centres' as a mechanism for overcoming crowded urban cores, decreasing commuting and distributing economic opportunities more broadly. In Shanghai, the Comprehensive Plan 2017–2035 anticipates five new urban sub-centres despite just 8.9 per cent of the population of the city dwelling in such sites. However, the authors cautioned that the strength of the central core of Shanghai and associated bid-rent curves for urban land mean that the city risks remaining imbalanced in terms of its employment and residential land-use distribution. They argued for the introduction of more employment opportunities in sub-centres. In a study of the spatial structure of Beijing, Zhao et al. (2010) noted the transport-related environmental costs of rapid urban expansion by examining the impact of commuting patterns on the outer fringes of the Beijing conurbation. The results back up those from elsewhere, which show that the land-use patterns adopted in Beijing suburban areas have a significant impact on commuting distance. This is seen to vary depending on access to public transport options and the nature of the workers' employment. Low-density development is shown to increase the need for long-distance commuting to the central urban area. The authors noted that compact urban development in the suburbs—particularly in the peripheral constellations of Beijing—would reduce the requirement for long-distance commuting (Zhao et al. 2010). While seen as laudable from a transport sustainability perspective, the provision of improved bus transport for commuters is shown to be a countermeasure in terms of reducing commuting, with the necessary service increases and road capacity encouraging more commuting, and increasing inner-city traffic congestion. The authors saw the integration of transport and land-use provision as being key to rectifying this situation.

Notably for this study, the extent and patterns of sub-centres in Australian cities has received attention from scholars, reflecting the longstanding, if episodically applied, policy attentiveness in such phenomena (Drechsler 2014; Moniruzzaman et al. 2017). In Melbourne, Goodman and Moloney (2004) noted the application of an 'activity centres' policy in the 2002 *Melbourne 2030 Metropolitan Strategy*. In the Melbourne case, the focus was on policies to cluster people-attracting land uses around public transport nodes rather than permitting market-based dispersion. This reflected historical efforts as represented in the first Melbourne planning scheme in 1954 and in the 1980 district centre policy. Although Goodman and Moloney (2004) welcomed the *Melbourne 2030* approach, they cautioned that definitional limitations combined with the number of designated activity centres weakened the potency of the policy. In a subsequent study, Goodman and Coote (2007) found that the *Melbourne 2030* policy was not being adopted in practice in terms of the location and design of new activity centres. This was partly due to the lack of public transport infrastructure in new growth areas but also because the land-use mix in activity centres was focussed on commercial and retail activities, with little community or public infrastructure. Similar findings were reported by Day et al. (2018) who concluded that despite many decades of policy

encouraging activity centres in Melbourne, negligible impact on jobs–housing balance could be identified. Indeed, Day et al. (2018) suggested that, at worst, there was a converse effect, with activity centres exhibiting worse jobs–housing balance than non-activity centres. They argued that there is more to activity centre policy than simply planning designations and that local place-making and capacity-building may be fruitful factors to consider. It should be noted that Yamashita et al. (2006) offered a contrary view to Day et al. (2018) and Goodman and Coote (2007). The first of these discussants suggested that Melbourne's activity centres have been successful —automobile-dominated travel notwithstanding.

International practice

The policy options touted for attracting high-value jobs to fringe suburbs and areas that have recently suffered economic decline are discussed by several experts within the context of the US (Chicago Booth Review 2017), which focused on how to create middle-class jobs in certain areas. The term 'middle class' is taken to mean *skilled*, rather than *white collar*. The options discussed range from Keynesian supply-side measures driven by government, to governments moving away to allow the market to create enterprise zones. The issue of growth towns is discussed, as they often have significant institutes of higher education and a younger population. Among the solutions offered in the Chicago Booth Review were:

- supplying infrastructure
- modifying land-use regulations and labour laws
- making it easier to start businesses
- utilising tax incentives
- investing more state money in training skilled workers locally
- lessening state-based regulations to allow portability
- increasing local research and development hubs, capital grants
- investing in vocational training.

Some governments offer incentives for businesses to relocate. Aster (2007) stressed the need for strong local partnerships and cooperatives. Miceli and Sirmans (2007) suggested further research into the use of '*eminent domain*' for urban redevelopment. Eminent domain is when the state can expropriate land for development purposes—which may be of value for brownfield or declined industrial areas.

It would appear that to lessen the problem of commuting by car, the state will need to either:

- provide incentives in the form of taxes or grants for non-service employers to relocate
- specifically pump-prime areas with state institutions, such as educational establishments or government departments of facilities.

Moreover, investing in high quality local infrastructure should play a role in further attracting skilled workers, although high quality travel alternatives to the car will be needed so as not to move car trips previously from and to the city centre to a local domain.

Australian practice

For the major Australian cities—with a strong focus on Sydney—Rickwood and Glazebrook (2009) used disaggregate data from the collection district level to gauge the relationship between urban form and travel behaviour. (Studies looking at the relationship between urban form and travel behaviour generally use spatial information at a coarse metropolitan or local government area scales.) The analyses suggested that the relationship between travel behaviour and urban form is extremely complex, and that simple analyses of density alone are likely to overstate the population density on mode choice.

3.3.2 Improving public transport on the urban fringe

Summary

The expansion of metropolitan areas typically requires consideration of infrastructure servicing. In many jurisdictions, metropolitan expansion through urban development proceeds in advance of infrastructure. While basic infrastructure servicing of water, sewerage, telecommunications, energy and roadways is typically ensured, less effort is often dedicated to public transport provision. This is often justified on the basis of the recurrent cost of providing viable service levels when demand has not yet been established, as residential populations are not yet in place. The consequence of such arrangements is that car use becomes entrenched, which reduces the viability of public transport service provision.

While there is a view within the literature that basic conventional public transport service provision is viable on the metropolitan fringe and ex-urban zones, much policy discussion in relation to such areas has focussed on paratransit and similar services. Paratransit has been the focus of considerable effort over recent decades and there is evidence of regular efforts to generate innovation in this area. However, a stable viable model of urban fringe and ex-urban demand-responsive transit is not yet confirmed as established apart from very specialist tasks such as disability mobility.

Domain discussion

Public transport is a combination of service and infrastructure. In many jurisdictions, including Australia, new urban growth is not necessarily accompanied by extensive public transport provision. Given the costs of infrastructure and services, governments have been reluctant to expand public transport networks in fringe areas where car-based travel is already entrenched and where demand for public transport is uncertain. Accordingly, fringe areas typically exhibit high levels of car dependence (Currie et al. 2009; Currie and Senbergs 2007). The consequences of high levels of car dependence include:

- constrained access to employment opportunities
- high financial costs of car ownership and operation
- health effects from low levels of active travel (Kroen et al. 2019).

These negative consequences, combined with the need to provide services efficiently and at low cost, are drivers for potential innovation. New mechanisms to deliver public transport to the urban fringe could be considered innovative, as they would overcome a longstanding weakness in public transport and land-use planning integration. To a large extent, the task of delivering public transport on the fringe is the same as the task of reducing car dependence and declines in public transport through improved public transport network planning, as discussed earlier.

The term ‘paratransit’ has been used to describe a mix of arrangements that provide for public travel in the absence of a formal public transport service (Cervero 1997). It is also referred to as ‘demand-responsive transit’ (Enoch et al. 2020), dial-a-ride and ‘flexible urban transport’ or ‘cars on demand’ (Kent and Dowling 2016). In many developing countries, paratransit organised through the informal sector is a major mode of motorised travel for large segments of the urban population. In developed countries, where car ownership is affordable to large proportions of the population, paratransit has largely been a phenomenon of specialised transport markets where demand is presumed to be too low for scheduled public transport services. There have been many attempts internationally over recent decades to establish on-demand public transport in fringe areas, such as via paratransit or dial-a-ride schemes (Cervero 1997; Daniels and Mulley 2012; L. Davison et al. 2014; Enoch et al. 2020). Most of these have been based on the assumption that the majority of travellers will take responsibility for their own mobility via automobiles leaving a remainder of population who, for various reasons, are unable to do so. Such populations may include disabled or elderly passengers who are unable to drive.

Paratransit has been the focus of many efforts at innovation in cities of developed nations in recent decades. However, sustainable business and operating models have proven difficult to establish. This is because of the:

- relatively low passenger volumes compared to conventional public transport services
- difficulties in establishing operators who are prepared to deliver services in uncertain regulatory and funding environments
- optimisation of vehicle types relative to passenger demand
- challenges of booking and hailing of services (Daniels and Mulley 2012).

There have been various attempts to program service algorithms that can optimise for service availability and passenger demand, but so far these have not been able to overcome the various barriers (Molenbruch et al. 2017). Daniels and Mulley (2012) suggested that regulatory change is needed to improve the viability of flexible urban transport services, as well as improved information and education of users and operators.

Despite these impediments, Kaufman (2020) noted that as of 2020 some 47 paratransit services were operating across Australian cities, with a combined monthly ridership of over 75,000 passengers. Some of these services are dedicated to the task set, while others involve coordination of existing taxi services. Many of the services are based on the new mobile technologies, reflecting innovations in wider platform-based mobility provision.

There is some literature on the use of paratransit integrated with conventional public transport services (Phun et al. 2019), although this is largely focussed on developing nation contexts. However, it is worth noting the observation by Mulley et al. (2012) of jurisdictional differences in urban form and conventional public transport systems, such that paratransit tends to be deployed in European rural contexts that exhibit urban densities similar to those on the fringe of Australian cities. In such environments, the Swiss model described by Petersen (2016), which involved pulse-timetabled conventional public transport integrated with trunk networks, may be preferable to dial-a-ride models of paratransit. There have also been suggestions that new mobility platforms such as ride-hailing or MaaS may overcome the service deficits that paratransit tends to address, given the flexibility that such platforms offer. That said, ride-hailing and MaaS do not necessarily deliver services that are suitable to the conventional paratransit passenger, such as the elderly or disabled. Nonetheless, it is possible that particular ride-hailing operators may prefer to operate in contexts where paratransit would fill gaps in conventional public transport services.

Thus, there is potential for future innovation in combinations of paratransit, ride-hailing and MaaS integrated with conventional scheduled public transit networks. However, such innovations are unlikely to emerge without regulatory stimulus and financial incentives. There have also been suggestions that AVs may offer a solution to the problem of providing transit services in low-density fringe environments (Greenblatt and Shaheen 2015) as part of wider uptake of AV ride-hailing services. This would potentially reduce the costs of servicing low passenger-volume zones —however, the prospect of viable universal AV services at scale remains uncertain, despite the Waymo trials.

3.4 Innovation domain: Climate change and pricing

The appropriate allocation of transport resources has been the subject of debate among transport researchers over many decades. Transport infrastructure provision often involves large fixed costs with long payback times. Important questions in transport provision are:

- Who accesses transport infrastructure?
- Who pays for transport infrastructure?
- How is this payment undertaken?

The extent to which the benefits of infrastructure or services are directly specific to users or generally enjoyed by society at large in various ways has been a major topic of deliberation. In a similar vein, transport debates have also considered who should bear the negative costs of transport infrastructure as experienced through various forms of pollution, including greenhouse gas emissions. The determination of appropriate allocation mechanisms for transport infrastructure and services is thus an important issue in transportation.

Various allocation mechanisms can operate for transport infrastructure and services. Public provision of infrastructure and services is common, with the infrastructure open to legal users and costs covered by direct or indirect taxation mechanisms—such as general revenue or special excise in the case of road infrastructure. Much recent transport infrastructure debate concerns the extent to which use of transport infrastructure should be subject to pricing mechanisms. Particular concerns apply to the capacity to levy charges on infrastructure users that are commensurate with the cost of provision and the burden that their use poses. For example, toll roads have been extensively used to provide highway infrastructure, with tolls used to pay back the capital costs of provision. Likewise, fares for public transport are often designed to balance the benefits to the private user with the generalised public benefits of mobility and avoidance of negative externalities, such as automobile pollution and greenhouse emissions.

This section discusses innovation in the provision and pricing of parking and road space through road-user charging, and incentives to procure hybrid and electric vehicles. The latter could have been placed into the technology or infrastructure procurement section, but it was considered that despite the technology being constantly improved, the key issue with electric vehicles is getting costs down to improve their proposition relative to petrol- and diesel-powered vehicles in order to achieve greenhouse gas emissions reduction objectives.

The interface between the road and the fixed infrastructure—the kerb and footpath—is facing new pressures due to increased traffic, as well as:

- ride-hailing
- home deliveries
- need for electric charging stations
- rise of micro-mobilities.

With a range of actors developing visions of a shift from individual ownership of cars to shared but intensively used highly automated fleets, the balance between parking, drop off, pick-up, and movement could be radically different in future. Yet to date many governments allow a laissez-faire governance model to operate at kerb level (Marsden et al. 2020). There is also growing pressure for road use to be priced, including generalised distance-based charging, in order to achieve greater allocation efficiency. However, introduction of generalised road pricing has proved difficult to achieve, in part due to social and political concerns.

The extent to which there should be minimum parking requirements in new dense inner-city developments, and the degree to which residential on-street parking should be provided as a backup for residents (who use on-street residential parking schemes), remain topics for debate.

These domains remain open to innovation, including in relation to EV uptake, road pricing and improved parking-pricing regimes and regulation. However, these areas face policy and institutional challenges that limit the pace of current change.

3.4.1 Electric vehicles (EVs)

Summary

For the purposes of this analysis we treat EVs principally as a climate-mitigation technology, as the main objective of an EV transition relate to fossil fuels and carbon emissions. There are numerous incentives currently in place globally to encourage the uptake of EVs. These cover purchase rebates, tax exemptions and tax credits. They also cover incentives that range from access to bus lanes to waivers on fees: parking, toll roads, user charging. The magnitude of the financial incentive is driven by the vehicle type and the size of the battery. Some countries not only incentivise the purchase of EVs, but also conversions of hybrids and conventional cars to EVs, and fuel cell vehicles. China now offers a purchasing subsidy for electric cars and buses above a certain range. Japan offers subsidies for trading in a conventionally powered bus or truck for an electrically powered one. In South Korea, as the government rolls out charging stations, first-time purchasers of EVs are entitled to a capital grant. Austria, Belgium, the Czech Republic, and most other EU countries offer tax breaks to those who purchase EVs.

The major impediments to the adoption of EVs are the lifecycle cost of ownership largely driven by battery prices, and the significant degree to which charging infrastructure will be needed to overcome the relatively limited kilometre range of EVs, to enable the space to move away from what might be seen as the 'safer' options of hybrid technologies, or just cleaner fuel. Efforts to reduce battery costs and improve the distribution network are ongoing globally, but in order to achieve economies of scale and render EV technology a genuine consumer choice, purchasing incentives are needed in the form of exemption from taxes, road-user charging and capital grants for hybrids and electric vehicles. Battery prices are declining, but still not enough to make EVs price competitive.

Electric vehicle pricing offers a part commentary on the car dependency model; where cars are more convenient, moving the means of propulsion away from the internal combustion engine to electric propulsion can seem to be at least lessening the pollution at source. Some governments (at least in wealthier countries) have shown willingness to 'prime the market' with a series of incentives to encourage the uptake of hybrid vehicles, and some manufacturers have taken a commercial risk to 'seed' the market to prime demand.

There remain opportunities for innovation in the EV market—including technology improvements to achieve distance performance comparable to conventional vehicles—as well as purchase and ownership models that account for the typically higher upfront and whole-of-life cost for EVs. New financing and subsidy models are another potential source of public sector innovation in relation to EVs.

Domain discussion

EVs operate principally via electrically powered drivetrains that do not rely on conventional fossil fuels, thus providing advantages in terms of reduced carbon emissions as well as improved energy sufficiency. While in many jurisdictions grid electricity is largely drawn from fossil fuel-based generation, the greater efficiency of an electric drivetrain means that the level of carbon emitted per kilometre of travel is lower than in vehicles with internal combustion engines. Although various hybrid EVs currently exist using a combination of electric battery storage and internal combustion engine, fully electronic vehicles comprise a minority of sales in most jurisdictions. EVs have been subject to much debate about their desirability and feasibility over recent decades. To date, uptake has been modest, with Mukerjhee and Ryan (2020) reporting that EVs comprise just one per cent of new vehicle sales in both the EU and the USA. That said, at time of writing the Tesla electric vehicle manufacturing company had overtaken Toyota as the most highly valued automotive manufacturing company globally, with a market capitalisation of US$206 billion (Fox 2020).

There is a growing literature on the potential of EVs—but also on the barriers to their adoption. Lee and Clarke (2018) identify the major impediments to the adoption of EVs as being the lifecycle cost of ownership largely driven by battery prices, and the significant degree to which charging infrastructure will be needed to overcome the relatively limited kilometre range of EVs, to enable the space to move away from what might be seen as the 'safer' options of hybrid technologies—or just cleaner fuel. In turn, they note that despite declining battery costs, an EV is significantly more costly than a petrol-powered vehicle over the lifecycle of ownership or useful life.

Individual cell costs have reduced to almost 10 per cent of their 2010 price ($1,000 per kWh to $145)—and the authors expect this to fall further with production economies of scale. However, these costs, reflect the cost of standard batteries per se, not the ones required to give the greater kilometre range required to entice consumers to switch from hybrids or internal combustion engines. These higher costs necessitate a form of subsidy of cost offset in terms of initiatives, such as tax or charge exemption to encourage a switch. Yet these subsidies are proving largely generally unattractive to governments.

Other authors have identified further constraints on the mass uptake of EVs. These include 'range anxiety', where EV owners are concerned about the distance they can travel on a single charge, and the time costs of recharging relative to filling a conventional fuel tank (Ge et al. 2018). However, Adepetu and Keshav (2017) suggest that range anxiety is not as important a determining factor in EV adoption as the upfront cost of vehicle purchase, which typically exceeds that for an equivalent fossil-fuel-based vehicle in terms of make and model. This cost aversion holds, they argue, for situations in which purchasers receive five times the battery capacity, so it is clearly a more important issue than range anxiety. Similar findings were reported by Kim et al. (2017), who observed that key factors were the:

- relative price of EVs to equivalent ICE vehicles
- driving range
- breadth of choice of models within the market.

Kim et al. also suggested that access to recharging infrastructure was insignificant as a purchase factor for EVs.

Consumer characteristics have also been reported in relation to EV uptake. Javid and Nejat (2017) identified household income and education as positively associated with plug-in EVs, as well as density of charging stations and local fuel prices. In the context of the present study, it is worth noting that Rezvani et al. (2015) associated various household behavioural and attitudinal characteristics with EV purchase, including social norms and neighbour effects, plus pro-environmental sensibilities and a preparedness to adopt new technologies. They also recognise the 'symbolic' aspects of EV ownership in relation to perceived personal attributes.

However, Rezvani et al. (2015) also cautioned that the appreciation of technological innovation may be a barrier to EV purchase, as consumers anticipate even better technology if they are prepared to wait longer. There is some evidence that marginal cost becomes a factor in EV use. For example, Ge et al. (2018) found that owners of plug-in hybrid EVs tended to exhibit 'gas anxiety' and would charge their EV more frequently than owners of battery EVs in order to avoid fuel purchase. Palmer et al. (2018) suggested that total cost of ownership needs to be considered in EV adoption, and that the jurisdictions that have been most successful in widening market share for EVs are those that have provided ongoing subsidies to owners.

The rollout of charging infrastructure has been debated in the literature. Lee and Clark (2018: 2) argue that commercial success for EVs will require installing charging infrastructure that is 'accessible, easy to use, and relatively inexpensive—whether at home or in public locations'. The cost structure is outlined as:

- **fixed costs**—charging infrastructure installation, transformers, interface with utilities, ancillary equipment
- **variable costs**—price of electricity.

Lee and Clark described this sector as fluid and unstandardised, with a range of charging technologies being developed, and with more under development. Speed of charging is crucial: the current charging equipment —whether home- or office-based—is generally slower than charging alternating current (AC) and suits shorter trips. Direct current (DC) charges are faster, which makes them more suitable for rapid recharging on long-range journeys—but they are considerably more expensive. Home-charging is seen to be cheaper than commercial charging, which has implications for the types of businesses and trip purposes that can be utilised.

The need for government support for electric vehicle adoption has been recognised in the literature. Norway has been particularly prominent in encouraging the uptake of EVs, which now make up some 30 per cent of new vehicle sales. Mersky et al. (2016) identified incentives to EV adoption offered in Norway, including:

- exemption from road tolls
- access to charging infrastructure
- tax incentives
- priority access to dedicated roadway lanes.

However, in their analysis, access to EV-charging infrastructure and regional incomes were the greatest predictors of EV uptake, implying that targeted incentives are less significant than wealth and convenience factors.

In contrast, Bjerkan et al. (2016) identified purchase tax and VAT exemptions as critical incentives for more than 80 per cent of EV purchasers. Such exemptions reduce the effective price of EV purchase, and are thus economically equivalent to demand subsidies that increase the relative buying power of spending on EVs compared to ICE vehicles. In further contrast to Mersky et al. (2016), Bjerkan et al. (2016) note that income is a less important predictor in EV purchase, which in turn suggests that non-wealth factors are also important.

Beyond Norway, Mukherjee and Ryan (2020) assessed EV uptake in Ireland. They found that localities distant from public charge points, with higher educational levels and more long-distance commuters, with fewer young people and higher home ownership are more likely to see higher levels of EV adoption. Notably, they conclude that longer-distance commuters find the lower per-kilometre costs of EV operation attractive—a finding that goes against prevailing assumptions about range anxiety.

In an extension of thinking about EVs, Illgen and Höck (2018) examine the performance of electric vehicles in car-sharing schemes compared to petrol-fuelled vehicles. This informed a simulation exercise of the uptake of EVs under different charging scenarios for different models in different urban markets. The simulation showed how EVs could be competitive for short trips within urban networks—depending on assumptions relating to fuel and electricity prices—if marketed appropriately to certain groups and for certain trips. Although it was a hypothetical modelled exercise, the study shows the levels of thresholds that will need to be achieved to ensure fleet uptake.

The question of direct incentives has been investigated. Sheldon and Dua (2019) argued that rather than offering blanket discounts or rebates on EV sales, governments should craft incentives to particular income or geographical groups. They also suggested that discounts should be related to vehicle battery capacity, rather than to the vehicle overall. Clinton and Steinberg (2019) assessed financial incentives for EV purchase and reported that between 2011 and 2015, vehicle rebate incentives were associated with an increase in overall EV registrations of approximately 11 per cent. However, they cautioned that the effect of subsidies offered as tax incentives is weak. They also noted that the subsidies had limited value if viewed solely in terms of emissions abatement, but could be considered worthwhile in terms of wider effects on market take-up of EVs.

International practice

Globally, the efforts to reduce battery costs and extend the distribution network are ongoing, but in order to achieve economies of scale and render EV technology a genuine consumer choice, purchasing incentives are needed in the form of capital grants and exemption from taxes and user charging. These incentives are for both hybrids and EVs.

Although the purchase of hybrids has been left to the individual, some governments in wealthier countries have been willing to ‘prime the market’ with a series of incentives to encourage the uptake of hybrid vehicles. Some manufacturers have also taken a commercial risk to ‘seed’ the market to prime demand. Japan would appear to have been the most radical jurisdiction, combining tax credits for hybrid purchases (to the value of the incremental cost of the hybrid) with higher petrol taxes. This has led to a rapid rise in the uptake of hybrid vehicles. For this reason, the Toyota Prius has been the bestselling car in Japan in some years.

An early initiative that received significant media attention was the 2011 hybrid tax credit offered by the US Government, known as 'cash for clunkers'. Apart from federal initiatives, individual US states also offer tax breaks for hybrids, with Colorado being the most generous. In other states, more modest incentives are in place, such as hybrid owners being:

- allowed to use high-occupancy vehicle (HOV) lanes regardless of the number of passengers carried
- entitled to free parking at select central city locations.

Sweden offers a capital grant of approximately US$1,600 to purchasers of hybrids. In Canada, residents of British Columbia, Ontario and Quebec can claim a sales tax rebate when purchasing a hybrid. In the UK, hybrid vehicles are charged the lowest car tax, and in London hybrid drivers do not have to pay the congestion charge.

Globally, there are numerous incentives currently in place to encourage the uptake of EVs. These cover purchase rebates, tax exemptions and tax credits. They also cover incentives that range from access to bus lanes to waivers on fees: parking, toll roads and user charging. The magnitude of the financial incentive is driven by the vehicle type and the size of the battery. Some countries not only incentivise the purchase of EVs, but also conversions of hybrids and conventional cars to EV, as well as fuel cell vehicles. China now offers a purchasing subsidy for electric cars and buses above a certain range. Japan offers subsidies for trading in a conventionally powered bus or truck for an electrically powered one. In South Korea, as the government rolls out charging stations, first-time purchasers of EVs are entitled to a capital grant. Austria, Belgium, the Czech Republic and most other EU countries offer tax breaks to those who purchase EVs. In Germany, 26 car and van models entitle their purchasers to a 'plug-in' bonus. In 2019, the Canadian Government introduced a program of incentives for zero emission vehicles, provided the vehicle price is above a certain threshold. In Morocco, imported hybrids and electric cars do not incur customs duty.

Because of their potential to reduce carbon and other pollutant emissions from motor vehicles, EVs retain potential for innovation in terms of design and as mechanisms to achieve greater adoption. However, it is likely that further innovation in design, policy and regulation will be needed to achieve the sustainability transition anticipated through EV development.

3.4.2 Road pricing

Summary

Road pricing involves placing a cost on the use of road infrastructure to achieve public objectives, and schemes fall into several categories.

The theoretical case for road-pricing schemes is well established, as a substantial literature attests. However, such schemes tend to face public opposition when democratic participation in decisions about introduction is allowed. Given the political sensitivity around generalised road-pricing schemes, there are few schemes of this type in operation globally. This provokes questions for innovation in road-pricing schemes: might the innovation be in how it is sold to the public as a package, rather than in the system itself? It is also seemingly easier to keep a tolling system in place that was used for financing, rather than retrofitting an existing asset with tolls—as the urban toll ring in Oslo demonstrates.

To convince the general public of the benefits of a road-pricing scheme, it seems that a trial period, to placate initial concerns, is the most successful way to bring about the long-term success of a project. London's charging zone applied tolled access to a certain part of the city on the basis that it offered a number of urban benefits:

- reduced traffic, noise and pollution in central London
- revenue to be used to support better public transport.

The scheme has persisted for nearly 20 years, and a new 'low-emission zone' has been added to reduce the use of polluting vehicles. In Milan, Stockholm and Singapore, trials took place before the introduction of road tolling, with lengthy public feedback throughout the process before the schemes were made permanent.

Equity issues—such as not discriminating against poorer sections of the community—can be alleviated with reinvestment of the revenues into infrastructure, parallel routes and improved public transport services.

Road pricing remains a domain that is open to innovation, not only in relation to technologies that provide for less intrusive road-use recording, but also to institutional models. Road pricing has the potential to advocate for the wider benefits that would accrue from price signals that reduce road use at the same time as raise funds for broader environmental and transport objectives, which could secure popular support for scheme introduction —if communicated effectively.

Domain discussion

Road pricing refers to the application of charges for the use of road infrastructure. Roads have been tolled selectively since antiquity, whether for financing or as a means of gathering tax. Since the expansion of automobile infrastructure from the mid-20th century, there have been debates about the application of pricing for roads:

- to cover capital costs of infrastructure provision (Friedman and Boorstin 1996)
- as a road-capacity rationing mechanism (Anas and Lindsey 2011)
- to internalise the costs of road use (Anas and Lindsey 2011).

Where the latter two purposes occur in dense urban locations, they are sometimes referred to as congestion charges, as is the case of London, which implemented one of the best-known examples.

The academic literature based on road pricing is largely characterised by an ageing body of work. References abound in the 1990s and 2000s, but have tapered off in recent years. This is presumably because much of the earlier work was produced by economists demonstrating the theoretical soundness of road pricing as a way of internalising economic externalities in the way road access is priced, and in the 2000s because papers were examining the effectiveness of schemes such as that of London (Santos and Fraser 2006). There are also modelling papers showing the cost-benefit profile of planned or theoretical schemes. However, since then the technical challenges of implementing generalised road pricing—and the political difficulties of 'selling it to the voters'—have led many authorities to become risk-averse around the topic. While enabling legislation exists in many places, actual on-the-ground schemes are scant, at least for cordon pricing models which charge for entry to a defined urban zone, as opposed to toll roads which tend to be used for funding specific road links.

There has been considerable research interest in assessing road-pricing mechanisms. May and Milne (2000) modelled four road-pricing systems in Cambridge UK, with charges based on:

- cordons crossed
- distance travelled
- time spent travelling
- time spent in congestion.

Their results show that congestion-pricing analysis offers insights into which different types of journey contribute to congestion. It seems to achieve reductions in travel at lower levels of charge, but is far less effective in reducing distance travelled. The results suggest that when rerouting effects are included in the predictive modelling process, the benefits of road pricing may be significantly smaller than previously expected.

Armelius and Hultkrantz (2006) described modelling work in the build-up to the introduction of the polit scheme in Stockholm in 2006, where road pricing was bundled with public transport improvements—that is, the road charge helped directly fund improved public transport. Armelius and Hultkrantz found that in the absence of revenue recycling, road commuters initially gained from the road-toll reform, but this changed when public transport improvements were initiated. The polit scheme was adopted permanently in 2007. Brownstone and Small (2005) compared results from evaluations of two recent road-pricing demonstrations in southern California, measuring commuters' values of time and reliability. Both sets of studies found that the value of time saved on the morning commute is high—between $20 and $40 per hour—when based on revealed behaviour, and less than half that amount when based on hypothetical behaviour. This shows that the actual benefits are often higher than those anticipated by models or user subjective perception, which may account for some of the opposition to road-pricing schemes.

Rotaris et al. (2010) found that the 2008 Milan Ecopass congestion charge had a negative effect on both emissions and congestion, while facing few implementation barriers and meeting with general political acceptance. However, Rotaris et al. (2010) also noted that the scheme did not necessarily raise sufficient revenue to cover its direct costs, thus necessitating some net public expenditure. Ison and Rye (2005) focussed on London's successful congestion charge in contrast to schemes in Hong Kong and Cambridge that were not implemented. They argued that a mix of factors underpinned the failure of the latter schemes, including insufficient extant congestion in the case of Cambridge, along with weak policy objectives and problems with user privacy concern.

Some studies have focussed on road-user acceptance of new pricing arrangements. Jakobsson et al. (2000) investigated the determinants of private car users' acceptance of road pricing. The estimated model, based on over 500 surveys, showed that acceptance of road pricing is negatively affected by a perceived infringement on freedom, and increased unfairness. This acceptance of road pricing increases in line with income, and an expectation that others will also reduce their car use—that is, there is no 'free rider' problem. In recognition of concerns about distributional effects, Levinson (2010) asked whether road-pricing strategies are regressive or progressive and focused on the issue of social inequality in universally charging groups for accessibility. He concluded that the theoretical and empirical literatures are mixed in their view, and this is to do with the plethora of road-pricing strategies and different definitions of equity. Levinson (2010) also noted that while there are significant equity issues, these can be lessened through sound design and by deploying the revenue generated to achieve equitable ends, such as cutting other taxes and investing in infrastructure and services. Santos and Rojey (2004) showed that road pricing can be regressive, progressive or neutral, and refute the generalised idea that road pricing is always regressive. Cools et al. (2011) examined the theoretical effects of road pricing on people's travel behaviour. Using a two-stage model, they surmised that behavioural changes themselves did not depend on the perceived acceptability of road pricing itself. The insight for policy-makers is that road-pricing charges may have to surpass a minimum threshold in order to entice changes in activity travel behaviour.

In what was perhaps the most comprehensive review of road-pricing schemes at the time of publication, Tsekeris and Voß (2009) observe that most of the literature on road pricing has focussed on theoretical development and options modelling. In contrast, evaluations of actual pricing schemes in practice have been much rarer. They argue in favour of an integrated evaluation framework that incorporates road-pricing considerations in scheme design, as well as integration with public transport, and wider spatial planning concerns..

In the US, Schaller (2010) notes that the public generally (as elsewhere) see road pricing as undesirable and a tax. Using New York as a case study, Schaller states that gaining approval of road pricing will require changing how motorists view the effect of pricing on them personally: schemes need to be shown to be perceived as benefiting drivers individually, not just society as a collective.

International practice

Road-pricing schemes fall into several categories. Given the political sensitivity around them, there are few in operation globally. When schemes have gone to a public referendum, as in Manchester or Edinburgh, they tend to be opposed as a 'tax' and resoundingly voted down. For example, enabling legislation has been in place in Sao

Paulo, Brazil, since 2012 but the prospect of this moving towards a referendum for approval reduces chances of success. This provokes questions in innovation in road-pricing schemes: might the innovation be in how the scheme is sold to the public as a package, rather than in the system itself? It is also seems to be easier to keep a tolling system in place that was used for financing by retrofitting an existing asset with a toll—as the urban roll ring in Oslo demonstrates.

In terms of cordon schemes, some smaller medieval cities restrict car access and only allow paid access at certain times of the day—for example, Durham and Valetta. Major city cordon pricing projects exist in Singapore, London, Milan and Stockholm. In Singapore, the 1975 area licensing scheme was upgraded in 1998 to electronic toll collection (tags) with a flat charge. Variable time-of-day pricing has yet to be introduced. This scheme was introduced following a lengthy and well publicised trial in the media. In London, the cordon charging scheme was introduced in 2002. It is based upon licence-plate recognition, and there are exemptions for categories of users. (This shows the overlap with some of the other innovation categories, as EVs are an exempted category.) In Milan a pilot project to introduce a pollution charge in 2008 was upgraded to a congestion charge in 2011. In Stockholm, a seven-month trial scheme was implemented as a permanent project in 2006. It is notable how most of these schemes have required a trial period to show effect and political will.

Toll road schemes effectively price entrance into a city. There are three toll road schemes in Norway—in Oslo, Bergen and Trondheim—which have been operating since the 1990s, with some peak pricing existing in Trondheim. In Santiago, Chile, the tolled highway passing through the city centre acts as a defacto congestion charge. High-occupancy vehicle lanes could be argued as being a form of congestion charge. Jakarta introduced a '3 in 1' scheme in 2002, with on-the-spot fines between certain times. There are high-occupancy vehicle tolls on motorways throughout the USA and Canada. Variable tolling is also in place on certain assets that regulate access to a city, such as the Harbour Bridge in Sydney, and the tolled tunnels and bridges in Manhattan. Various other pilot projects are in place in the US, such as variable price of day parking in central Chicago.

In terms of innovation potential, road pricing remains a major policy gap. In Australia there is wide policy consensus about the need for improved allocation efficiency for major urban roads, with pricing schemes viewed as the most efficient (IA 2018a; IV 2020; Productivity Commission 2017; Terrill et al. 2019). However, there is a paradox in the Australian context, as existing high levels of car dependence and high levels of urban road-capacity utilisation have developed in part on the absence of accounting for negative externalities. Thus, reining back this 'free lunch' through pricing schemes is politically contentious as it involves imposing a cost on a good that has previously been viewed as free, so there a wide electorate of opposition to generalised road pricing. Nonetheless, a form of specific road pricing has developed through the use of tolling for new road infrastructure in Sydney and Melbourne, which has begun to exhibit some generalised network-pricing characteristics. There remains potential for innovation in the design of comprehensive road-pricing schemes for Australian cities to be accompanied by innovation in the institutional and political dimensions of acceptance and implementation. One concern in the Australian context is that individual companies monopolise road tolling. This issue would need to be addressed if generalised network pricing were to be established.

3.4.3 Parking pricing

Summary

Car parking is a necessity in cities where a high proportion of trips are undertaken by private car. However, the quantity of public space required for car parking (as 'on-street' and public parking lots) to the exclusion of other uses means that rationing is often necessary. The use of private land for 'off-street' parking is largely subject to the interplay of:

- planning regulations
- land value
- construction costs
- ability to recoup costs
- accessibility by other modes of transport.

Technology can be an aid to improved car parking regulation. However, many of the challenges are institutional —and to some extent cultural—where heavy reliance on automobiles brings expectations of free public provision for their use. Pricing is often used as a rationing mechanism; however, as with all pricing regimes, this raises various issues, including distributional consequences and political acceptability.

There remains potential for innovation in the domain of car parking pricing in terms of technologies, regulations and institutional models. However, this needs to be understood within the generalised framework of support for automobile travel, in that parking is a consequence of wider settings even if it is often the most prominent.

Domain discussion

Urban automobiles are immobile for 90 per cent of their functional life (Shoup 2017). When not being driven they are typically parked. In highly automobile-dominated cities, parking is a major form of demand for urban space, while parking-search components of vehicle trips add to road congestion. Yet parking is typically provided free of charge in many jurisdictions. Like the pricing of road capacity through tolls or congestion charges, pricing of car parking is a contentious issue in transport policy. Many observers consider prevailing parking-pricing regimes to be inefficient as they do not pose a sufficient price signal that covers the full social costs of motor vehicle storage. High levels of car dependence and the widespread sense of entitlement to something for free, as with road pricing, make reform to parking-pricing regimes difficult to achieve. Further challenges are likely to emerge in future in relation to car parking should AVs become commonly used. An under-appreciated aspect of AV uptake—particularly if used as taxis or via ride-hailing platform—is kerbside demand, which in most instances is currently a free good. Thus there is considerable potential for innovation in the design and application of car parking regimes in cities (Shoup 2020).

Various scholars have assessed the land-use impacts of car parking. González-González et al. (2020) felt that planners were struggling with the potential impacts of AVs on land use and locational impacts, most notably for road space and parking. Their study used a back-casting approach to identify critical policy decisions and measures to be taken before the implementation of AVs, so as to achieve more desirable, attractive and high quality cities. The policies articulated largely relate to the reallocation of parking and road space. González-González et al. saw a clear commitment to shared mobility as essential to the successful implementation of AVs.

The consequences of car-parking pricing regimes have been investigated by scholars. Ostermeijer et al. (2019) found that residents are often offered on-street parking at a fraction of the market price, which is a variable in deciding whether or not to buy a car. As residential parking costs are difficult to estimate, Ostermeijer et al. devised an approach to estimate *implicit* residential parking costs and then examined the effect of these costs on household car ownership. They showed that across four major metropolitan areas in the Netherlands, the disparity in parking costs could explain around 30 per cent of the difference in average car ownership rates between cities and suburbs, corresponding to a price elasticity of car demand of around −0.7. In extrapolating this finding, it is suggested that if residents' car-parking permit schemes were abolished, car demand in city centres may increase by between 8 and 14 per cent.

In further thinking about the impacts of AVs, Marsden et al. (2020) described how the kerb acts as the critical site of interaction between people and vehicles, and movement and place, and remains a heavily congested space that is difficult to govern and manage. The kerb is not only being heavily affected by ride-hailing and an increased volume of home deliveries, but also by new mobility technologies such as e-scooters and e-bikes, as well as a likely demand for electric charging points. With a range of actors developing visions of a shift from individual ownership of cars to shared but intensively used highly automated fleets, the balance between parking, drop off, pick-up and movement could be radically different in future. Drawing on the literature on boundary objects, Marsden et al (2020) explore how different user groups manage their own interests at the kerb level, and the power relations that exist between the different groups. The authors makes the case for public policy to reassert itself in the kerb debate through regulation in a bid to balance commercial and social interests (Marsden et al. 2020). Ferreira et al. (2020) described how the Zona Azul Digital scheme in Sao Paulo was upgraded in recent years from paper passes to digital technology.

The use of car parking as a means of accessing public transport (Park and Ride, or PnR) has also been discussed. Kimpton et al. (2020) flagged how these schemes emerged to accommodate motorists that would have otherwise depleted the supply of parking around train stations and other high-occupancy modal nodes. However, they note that PnR evolved into a planning strategy to provide commuters from auto-dependent suburbs with access to rapid high-occupancy vehicles. The authors note that PnR should increase the percentage of people choosing to use public transport by making transfer more convenient—yet this is not usually the case (Kimpton et al 2020). A synthesis of the PnR literature by Kimpton et al. (2020) suggested that motorists contemplating PnR have multiple considerations beyond minimising their travel duration and expenses. The authors develop a model to show the integration of PnR, multi-modalism and modal choice to illustrate how initiatives such as transit-oriented development and active transport interact and inform modal choice (Kimpton et al 2020). The research findings suggested that it is new rather than modified PnR that influences modal choice, and that new park-and-riders are typically drawn from nearby locations rather than peripheral and auto-dependent areas. This influence is particularly evident in suburbs closer to the inner city—and these are not the intended recipients of PnR schemes. Chen et al. (2016) presented a methodology to identify optimal locations and capacity for rail-based PnR sites to increase the mode share of public transport.

Parking is sometimes viewed within more generalised travel demand management frameworks. Lari et al. (2014) suggest that parking pricing has gone beyond being a tool for generating public revenue and has shifted to a public policy tool for managing travel demand. They examine the effects on commuter mode choice of introducing flexibility and incentives into monthly parking contracts. Four test models were operated over three months:

- a discounted transit pass option (Buying Flexibility)
- a rebate program (Marginal Rebate)
- another rebate program (PayGo)
- a free transit pass option (Disincentive Removal).

The analysis of the subsequent commuting behaviour among study participants demonstrates that the level of financial incentive and flexibility positively correlates to the propensity for mode-shift to occur, with significant and increasing mode-shift in the two programs that offered the greatest flexibility and incentive. However, what is more important from a policy perspective is that a free or discounted travel pass in its own right does not incentivise modal change. The 'stick' seems to have a stronger effect than the 'carrot' in this context—but the stick brings political risk and contention.

Some authors discuss the use of technology in parking. Mainetti et al. (2014) described a radio-based frequency trial of guiding parking entrants to vacant spaces using customised software. The integration with an 'e-wallet' allows users to pay the parking fee. In addition, a software app is in place to manage alert events—such as the improper use of a reserved space or expiration of the purchased time—and trigger parking enforcement systems. Verma and Verma (2015) also focussed on 'smart' parking systems. Manville (2020) noted how the smart meter Expresspark scheme operates in Los Angeles to ensure the price of curb parking varies according to demand.

Meanwhile, the intersection of car parking with residential land uses has also been canvassed in the literature. Taylor (2020) described how some observers felt higher-density housing with insufficient off-street parking, combined with conventional minimum parking space legislation, is underscoring calls to strengthen on-street parking requirements close to new developments. Yet, despite this, there is little evidence as to who uses residential on-street parking, nor is there clear evidence as to the extent to which off-street parking, or requirements for it, actually offset on-street parking use. Taylor (2020) presented findings of a study from Melbourne showing how in one location most users of on-street parking have sufficient off-street parking, and half use garage space for storage or housing purposes. Residents of new flats and apartments account for little on-street parking use. Critical analysis is offered on both the capability of conventional 'predict and provide' parking policies to manage residential parking, and how to cope with urban change. Mingardo (2020) noted how the end of 'predict and provide' parking in Rotterdam 20 years ago created a more attractive inner city for both visitors and residents.

International practice

Pojani et al. (2019) examined parking policies in 12 cities on five continents: Auckland, Bangkok, Doha, Los Angeles, Melbourne, Nairobi, Rotterdam, Santiago, Sao Paulo, Shenzhen, Singapore and Tokyo. Pojani et al. discuss parking within the context of planning, land-use, mobility, society and technology. Barter (2020) noted that transport policies in Singapore are integrated with land use to foster transit-oriented development, and limit car usage and ownership. Yet Singapore's parking policies remain reasonably conventional, with minimum parking requirements and the matching of supply and demand. Yet despite not being perceived as at the cutting edge of parking policy, Singapore has moved slowly towards managing the effects of parking through initiatives such as 'walkable parking' —making sure that busy areas are park-once-and-walk districts in which much of the parking is open to the public and managed through pricing.

In Doha, Furlan (2020) noted how, despite the presence of predict and provide policies, the city has adopted some parking policies to reduce car dependency, including the replacement of surface parking lots and on-street parking with underground parking facilities to foster the regeneration of historic districts. Meanwhile, Nunns et al. (2020) described significant developments in Auckland, where policy changes have helped adjust parking supply and prices to a more economically efficient level, so car parking charges can cover the costs of car-parking provision. Auckland established maximum parking limits to stimulate denser residential development in the city centre, and this was subsequently extended to outer districts. Auckland's approach—in mirroring successful road-pricing schemes—hinges on the use of low-cost trials to gather evidence and build the case for further changes to policy. Nunns et al. (2020:148) noted that the "The effectiveness of Auckland's approach, therefore, depends on the capacity and effectiveness of public institutions and policy settings, rather than financial resources". The Auckland case, Nun et al (2020) argue, has achieved a decline in the per capita supply of parking, and parking prices closer to the marginal cost of supply.

Parking is an overlooked area of transport policy and planning in cities (Shoup 2017). Consequently, parking is open to innovation in terms of mechanisms for recording usage of parking infrastructure, charging regimes that can achieve public objectives, and institutional and political settings that can accommodate greater charges for parking.

3.5 Innovation domain: Infrastructure procurement

While much of the focus of policy discussion about transport innovation emphasises technological innovations, this study has emphasised the importance of also understanding institutional innovation as recognised in the innovation literature. Transport infrastructure is a major form of capital investment, and recent decades have seen new arrangements for coordinating and financing major transport infrastructure projects. Governments continue to face budgetary pressures that generate demand for new ways to obtain public value from projects through innovative funding and financing arrangements.

This section considers infrastructure procurement as a domain of innovation in urban transport, focussing on value capture and public–private partnerships (PPPs), which typically involve structured construction and financing agreements between:

- governments that sponsor and regulate the project
- constructors that build the project
- financiers that coordinate the funding of the project.

These mechanisms have historical precursors (such as turnpike roads) but have seen greater use since the 1980s as vehicles for urban transport infrastructure. While there is a reasonably settled model for PPPs, they remain controversial because of suspicion of rent-seeking by private organisations through either:

- excessive capture of public funding
- disproportionate income streams
- distortion of project objectives.

Nonetheless, PPPs remain a potential domain of innovation within the urban transport sector and can deliver good public value if suitably regulated.

The remainder of this section considers the use of value capture as a public-private financing mechanism for urban transport infrastructure.

3.5.1 Value capture for funding projects

Summary

Value capture involves contributions from parties who are material beneficiaries—typically landholders—of an infrastructure development towards the cost of procuring that infrastructure. If implemented carefully, value-capture models can be a robust financing alternative that could effectively support sustainable urban development (Roukouni et al. 2014); and it is worth noting that urban land-use development projects have generated revenue for transport schemes that strengthen their financial viability (Mathur and Smith 2013).

Transport investment and infrastructure nearly always influence nearby land values because of an uplift in accessibility and economic activity. This effect tends to be long-term, enabling a component of the rent-stream to be used to fund the infrastructure. Several jurisdictions around the USA utilise a value-capture technique embedded in their property tax to finance infrastructure and motivate affordable compact development (Rybeck 2004).

Joint development projects benefit from supportive land use and zoning, as well as clear policy objectives and political direction. Inflation-adjusted guarantees and revenue sharing are shown to be of assistance in taking the risk out of value capture as a financing mechanism. Cities where value capture has been successfully deployed include Denver, Atlanta, Hong Kong, Washington and London.

Value capture is rarely used in Australia, making its application in this jurisdiction a potential innovation in both infrastructure and public policy generally. However, from an historical perspective, Australia could be seen as an early user of value capture because of the 19th-century use of railways to open up ex-urban land for residential development, with the value gains from land sales used to fund the infrastructure (Davison 1974).

Domain discussion

Concessionary infrastructure schemes involving PPPs and build-operate-transfer arrangements were considered innovations in the 1990s as an alternative to direct government financing through taxation. Today they are considered a mature procurement instrument. PPPs have to some extent been 'derisked' through processes of trial and error, such that their current incarnation leaves very little demand risk with the private concessionaire; availability payment PPPs are now well understood, and this is a variation on a standard performance contract. Governments have also become more adept at crafting contracts with private partners to avoid rent-seeking and excessive draw on public funds, though this remains a point of debate (Johnston 2010).

Within the context of Australia, infrastructure bonds—as commonly used in the USA—may be seen as innovative, yet again this would be because they are not used in Australia: they are not a 'revolutionary' or new financing tool. What is topical in Australia is the notion of 'value capture'—that the public sector should be able to recoup some of the value it passes to the private sector when development takes place on government land, and through granted government licence. A good example would be the solutions being examined for the proposed Suburban Rail Loop in Melbourne. While much of the land may be privately owned, it is the accessibility contributed because the public sector is commissioning and operating a railway that will allow the developers to make a far greater development and rental yield than they would otherwise have obtained, and as a result the state deserves some of this for developing the infrastructure.

Land-value uplift is the fundamental feature of value-capture schemes. Rybeck (2004) observes how transport investment and infrastructure almost always influence nearby land values due to an uplift in accessibility and economic activity. This in turn causes an effect whereby the adjacent land requires infrastructure for its development, which is not usually forthcoming. Perversely, lagging transport infrastructure then forces further development, but without transit services, the areas can become car-dependent and economic activity can stagnate; however, this is true even if the transport infrastructure is road-based. Resulting urban expansion then strains the transportation, fiscal and environmental systems upon which communities rely. Rybeck (2004) notes how several jurisdictions in the USA utilise a value-capture technique embedded in their property tax to finance infrastructure and motivate affordable compact development. This value-capture technique reduces the tax rate on building values and increases the land-value tax revenue. As such, the development in the area becomes more compact, which in turn encourages more transport infrastructure. The techniques foster compact growth, with lower environmental and fiscal costs, which in turn reduces urban expansion, and reduces pressure on growth boundaries.

In observing how demand for transportation infrastructure and services keeps increasing, thus pushing up costs in an environment of public fiscal constraint, Roukouni et al. (2014) made a case for the role of accessibility in creating sustainable financing mechanisms—land-value capture. They conclude that if value-capture models are implemented carefully, they can be a robust financing alternative that could effectively support sustainable urban development. Mathur and Smith (2013) noted that development projects can generate revenue for transit agencies. Five development projects are offered as case studies, and it is shown that joint development projects benefit from supportive land use and zoning, as well as from clear policy objectives and political direction. Revenue sharing and guarantees adjusted for inflation are shown to be of assistance in derisking value capture as a financing mechanism.

Smith and Gihring (2006) suggested that much of the literature on value capture reports empirical findings on the incidence of rising land values related to distance from a transport node, and that these events are well documented. Consequently, they argue that the debate should move from the hypothetical to the practical and that longitudinal models, calibrated from elsewhere, could be used to support a financing instrument that would allow the debt financing of transport improvements.

International practice

Roukouni et al. (2014) present case studies in US cities of Denver and Atlanta. The Denver Union Station (DUS) redevelopment is a sub-project of an upgrade to Denver's commuter rail system—197 km of rail and light rail tracks, 29 km of bus rapid transit (BRT) and 21,000 parking spaces—estimated at a total cost of $7bn. Within this envelope the cost of developing the main station—DUS—is $500m. Much of this will be paid for through a value-capture mechanism and an enterprise zone of 20 acres around the station, for a period of 30 years. The revenue obtained from the value-capture mechanism will be used to pay off both the capital required to build the project, and to act as equity for borrowing for future development.

This financing structure is apparently unique—the first time that the Denver Department of Transport has combined the two financing methods within one project. In 2005, Atlanta's council approved a project of $2.8bn (for 6,500 acres [2630 hectares]) which covered a transit network, the creation of urban green spaces and community housing. More than 50 per cent of the project's financing ($1.7bn) is estimated to be collected through value capture by the creation of a 25-year Tax Allocation District. This covers structures that were abandoned or unused industrial buildings, and not residential buildings.

Infrastructure Australia (IA; 2017) described Hong Kong's ongoing value-capture program, the Mass Transit Railway (MTR), which integrates its transport infrastructure with property development. MTR partners with property developers to integrate properties such as office and apartment buildings and shopping complexes with MTR stations. While Hong Kong is perhaps a unique self-contained model, the approach, combined with other initiatives such as car-ownership restrictions, has resulted in MTR's operating and capital costs being entirely self-funded through a combination of fares, commercial station retail rents and joint property developments. It should be noted that MTR are the primary stakeholder in MTM, the company that operates Melbourne's commuter rail service under franchise.

In their discussion of value capture, IA (2017) also noted how Crossrail in London utilised a Business Rate Supplement (BRS) of two per cent on commercial properties with a rateable value of more than £55,000 in the Greater London Area to finance a chunk of the project. Income from the BRS will generate a £4.1bn contribution towards construction costs through direct funding and loan repayments. Voluntary contributions were secured from Heathrow Airport Holding Ltd (£70 million), Canary Wharf Group (£150 million) and other developers. In total, the value-capture measures funded around 35 per cent of the capital value of the project; the rest will come via paying back loans through fare revenue under a fixed-rate variable term loan.

Value capture remains underdeveloped as a mechanism for infrastructure financing in Australia. However, its application in the Australian context can be considered innovative, although this would necessitate a great degree of policy development to achieve viability. Usefully, such development appears to have began with Infrastructure Victoria (2016), for example, when it began a policy discussion about the principles and application of value capture for infrastructure funding in Victoria.

4. Domains of innovation: Australian policy

This section reviews the strategic approaches that Australian metropolitan transport programs and policies are adopting to configure infrastructure, technology, regulation and design. As outlined in Section 1, this work draws on a desk-based review of recent (2014–2019) metropolitan transport policy documents for a sample of three Australian cities: Sydney, Melbourne and Perth. This was supplemented by a review of emerging policy interests. Consistent with the international review in Section 3, the policy review focusses on the same 'domains of innovation' and seeks to identify major change drivers and common or divergent themes and directions. For each policy document, a content analysis was conducted—looking first for the presence (or absence) of policy discussion for each domain of innovation. Then an evaluation of each innovation item was made using a qualitative rating scale in order to provide a sense of the direction.

4.1 Strategic planning policy: State level

The most recent published transport policy documents available in the public domain produced by urban planning and transport planning state departments were selected for analysis. Three states were selected: WA, Victoria and NSW.

An overview of the coverage by 'domains of innovation' can be seen in Table 1. The overall picture is one where policy discussion is focussed predominantly on current transport modes—rather than emerging modes—and on land-use planning to facilitate sustainable transport. This sees a continuation of practices set in the late 1990s. In each of the three states, the conventional strategic urban-planning and transport-planning documents focus efforts on 'influencing travel behaviour' by seeking to reduce car dependency and suggest measures to improve public transport in order to address declining usage. Two policy documents (NSW and WA) also include a focus on encouraging telecommuting. There is also a strong focus in each state on urban structure—that is, looking to develop activity centres that are integrated with transport to lessen commuting.

In the current policy documents, both Victoria and NSW focus on emerging transport modes, considering MaaS, ride-hailing and car-sharing options and AVs. NSW also includes a focus on micro-mobility. Two documents evaluated for NSW differ in scope to the conventional urban planning and transport strategy documents. These are directly focussed on connected vehicles and AVs, and on electric and hybrid vehicles. Together they represent the more detailed plans of implementation as recommended by the earlier strategic-level state transportation plan *Future transport strategy 2056*.

Table 1: Australian state policies

		WA		VIC			NSW		
Domains of innovation	Sub-topic	Perth and Peel@3.5m The Transport Network (2018) DTMR	Perth and Peel@3.5m (2018) DPLH	Plan Melbourne 2017–2050 (2017) DELWP	Simple, connected journeys: Our strategic plan 2019–23 (2019) DoT	Movement and Place in Victoria (2019) DoT	Future Transport 2056 strategy (2018) TfNSW	Connected and Automated Vehicles Plan (2018) TfNSW	NSW Electric and Hybrid Vehicle Plan (2018) TfNSW
Transport platform	Mobility as a Service (MaaS)				■		■	■	
	Ride-hailing apps and car-sharing				■			■	■
	Micro-mobility						■	■	
	AVs			■	■		■	■	
Influencing travel behaviour	Lessening car dependency	■	■	■	■	■	■		
	Addressing declining public transport usage	■		■	■	■	■		
	Encouraging telecommuting/ shopping		■				■		
Urban structures	High-value local activity centres to lessen commuting	■	■	■		■	■		
	Improving public transport on the urban fringe			■	■				
Climate change and pricing	Electric vehicles	■			■		■		■
	Road pricing						■	■	
	Parking pricing								
Infrastructure procurement	Value capture for funding projects			■			■		

Sources: DTMR (2018), DPLH (2018), DELWP (2017); DoT (2019a), DoT (2019b), TfNSW (2018a), TfNSW (2018b), TfNSW (2018c).

An analysis of the policy content is shown in Table 2, organised by the five domains of innovation. An evaluation of each innovation item was also made using the evaluation criteria. For each criterion, we employed a qualitative rating scale in order to provide a sense of the direction—this ranged from a rating of 1 (red), where the impact was considered to be very low, to 5 (dark green), where the impact was considered to be very high. A description and explanation of the criteria and its significance follows.

Table 2: Evaluation criteria and rating scale

Evaluation criteria
Ability to operationalise
Scalability: from 'niche' market to mobility 'regime'
Potential for innovation
Access/inclusion: affordable, safe, legible
Potential for disruption of private car ownership model
Minimal disruption to PT
Minimal disruption to AT
Impact on policy debate to date
Extent of impact to date
Extent of disruption of private car ownership and use to date
Transferability

Very low (1)	Low (2)	Slight (3)	Moderate (4)	Very high (5)

Note: PT = public transport; AT = active transport.

Source: Authors.

Ability to operationalise

Ability to operationalise refers to the ability of the responsible authority to ensure practical on-the-ground implementation. This might be achieved via instruments such as new policy or legislation, standards or funding models. We consider this to be a crucial criterion for evaluating a planning document. Even a 'high-level' strategy must outline practical measures—such as future studies, additional stakeholder consultation or development of a detailed action plan—to avoid its prescriptions being seen as little more than aspirational statements.

Scalability: from 'niche' market to mobility 'regime'

Scalability refers to the potential of a promising new innovation to graduate from the narrow confines of a small market 'niche' to a mainstream solution, with widespread application across multiple mobility markets. The idea of a 'niche' and 'regime' are drawn from the multi-level perspective of societal change proposed by Rip and Kemp (1998). This criterion was selected because an innovation must be widely used in order to have a substantive impact.

Potential for innovation

Potential for innovation refers to the ability of a measure identified in a plan to contribute to some form of innovation. This innovation could be technical, organisational or conceptual. This criterion was selected because this study is looking at innovative aspects of recent plans. The potential for innovation is timely, given repeated failures to significantly address sustainability concerns by simply reapplying old ideas.

Access/inclusion: affordable, safe, legible

Access and inclusion underscores the importance of a proposed measure to be accessible and inclusive in the broadest possible sense. This criterion was adopted as it reflects the value of social equity.

Potential for disruption of private car ownership and use

The term 'disruption' is adapted from the concept of a 'disruptive innovation', developed by Christensen (1998). This refers to an established product or service being displaced by competition from a lower quality and less expensive new alternative. More recent adaptations of the term recognise that the 'disrupter' might also offer an alternative that is qualitatively superior from the day of its introduction. Given the negative environmental and social externalities associated with the 'system of automobility' (Urry 2004), an innovation that shows promise in 'disrupting' the car ownership and use model was seen as worthy of inclusion as a criterion—although this objective was debated among the PRG.

Minimal disruption to public transport (PT)

As public transport is a space- and resource-efficient means of moving city inhabitants about, minimal disruption to this business model is an important criterion by which to assess innovations in planning and transport.

Minimal disruption to active transport (AT)

Active transport is the most ecologically sustainable means of travel and is associated with good population health outcomes. So any inadvertent impact—including loss of market share—would be seen as an unfavourable development. Measures that achieve a beneficial outcome without inadvertently disrupting active transport are viewed favourably. The necessity of developing novel solutions to our sustainability problems without reducing active travel is the reason for inclusion of this criterion.

Impact on policy debate to date

The interest in impact on policy debate is whether the proposal is being picked up in the wider policy discourse. The criterion was selected as evidence of ideas having a wider policy impact and is reflective of more widespread consideration—a proxy of implementation potential.

Extent of impact to date

Extent of impact denotes the measurable consequences of a recommended intervention. Its selection reflects the importance of an innovation achieving a wider impact.

Extent of disruption of private car ownership and use to date

Extent of disruption refers to the impact a measure is already having on reducing ownership and use of private motor vehicles. The criterion was selected to reflect the significance of achieving lasting changes to urban mobility as envisaged by many transport policies.

Transferability

Transferability refers to the ability of an innovation to be applied to other jurisdictions. This is seen as an important criterion, as one of the keys to managing a successful sustainability transition is scalability, which can be achieved by widespread implementation across multiple jurisdictions.

4.1.1 Innovation domain: Transport service platforms

A focus on the 'emerging transport technologies' is an emerging area of policy within the state urban planning and transport documents. The two current WA policy documents (from the Department of Transport and the Department of Planning, Lands and Heritage) do not include content on this. As mentioned earlier, NSW has published two documents that are narrower in scope that focus directly on some of the disruptive technologies. We will discuss each sub-topic in turn.

Mobility as a Service (MaaS)

MaaS is tackled in two of the policy documents. Victoria's strategic plan sought to develop a 'digital one stop-shop for transport information' (DoT 2019a: 8) to cover multimodal travel and ensure real-time information. NSW's transport strategy (TfNSW 2018b) focussed on the data dimension as a key enabling element for MaaS but noted that the authority would require support from providers. TfNSW aimed to 'expand open data and data exchange initiatives to improve customisation of services and journey planning across providers' (TfNSW 2018b: 72). With this in mind, the policy noted the need to resolve issues relating to privacy, data protection and liability. The strategy aimed to 'lead innovation nationally, with a Data Science Incubator and Open Data policies across public and private services to enable safe and effective use of technology' (TfNSW 2018b: 72).

Ride-hailing apps and car-sharing

New South Wales supported the uptake of ride-share options, and asserted that in the future there will be new ride-share services and alternatives to car ownership. The NSW 2018 Connected and automated vehicle (CAV) strategy asserts that automated ride-sharing may offer customers affordable and convenient point-to-point journeys and flexible on-demand public transport, improving first-mile connections and enhancing mobility for people in underserved areas (TfNSW 2018a). TfNSW suggested that by dropping off passengers, CAVs may help to reduce congestion, on-street and off-street parking, the need to own a car, and help create more liveable urban centres (TfNSW 2018a:19). The *NSW electric and hybrid vehicle plan* (TfNSW 2018c) suggested that car-share or ride-share trials using EVs will be facilitated.

Micro-mobility

At this stage, NSW is the only state to set policies related to micro-mobility. The *NSW Future transport strategy 2056* (TfNSW 2018b: 62) seeks to enable 'shared use models in centres', in recognition that e-bikes and motorised scooters can be an effective first-mile technology for accessing local centres and public transport due to their low cost (especially if shared) and low effort—the policy indirectly acknowledged the potential to impact negatively on walking journeys by stating that the focus should be on locations just beyond walking distance of local centres and public transport (thus extending the reach of the latter). To allow for this, the strategy sought to complete cycle networks, pedestrian spaces and interchanges. The focus was on creating a safer environment.

Autonomous vehicles (AVs)

Plan Melbourne (Department of Environment, Land, Water and Planning [DELWP] 2017: 8) includes a high-level statement that 'recognises that new technologies including AVs will change working and living arrangements'. The document adds nothing more substantive but noted that the plan would need to be adapted over time to accommodate those changes. Two years on, the *2019 Strategic Plan* indicates Victoria's support for the uptake of AVs (Department of Transport, Victoria [DoT] 2019a: 15), referring to University of Melbourne's 'Multi-Modal Testbed' where driverless cars are being tested in a 'living lab' in inner-city Carlton. They asserted that in future there would be a 'rapid emergence of AVs' (DoT 2019a: 19).

In NSW there appears to be a more significant level of activity, with the statement made by the *Future Transport Strategy 2056* (TfNSW 2018b: 14) that NSW wanted to lead on the development and adoption of CAVs in order to 'enable and support others to develop these technologies and bring them to market—in a way that is legal, safe and delivers the best possible benefits to our customers and the community' (TfNSW 2018b: 28). The *Future Transport Strategy 2056* (TfNSW 2018b) recognised that shared CAVs could:

- reduce congestion
- extend the reach of public transport
- improve mobility and social inclusion for older and disabled people.

But the strategy also noted that if AVs were used individually and took mode share from public transport, this would lead to increased vehicle kilometres travelled and congestion and higher greenhouse gas emissions (TfNSW 2018b: 60).

The strategy is proactive in supporting shared AVs, calling for 'expressions of interest' for a regional CAV trial (TfNSW 2018b: 11), supported with $10 million in funding over four years, following legislation passed in 2017 to allow trials. The trials are to be assessed in terms of 'policy outcomes of improving safety, boosting service frequencies and reducing congestion' (TfNSW 2018b: 56). A two-year trial of a driverless shuttle bus was to be conducted at Sydney Olympic Park with delivery partners HMI Technologies, NRMA, Telstra and IAE (TfNSW 2018b: 59). The associated CAV plan notes regional AV bus trials at Coffs Harbour and Armidale beginning in July 2018.

The TfNSW strategy flags the development of a CAV Innovation Action Plan aimed at identifying infrastructure enhancements—such as high-contrast road markings and CAV drop-offs at rail stations—and setting up a CAV stakeholder reference group (later referred to as a 'Smart Innovation Centre' in the 2018 CAV plan). The reference group would engage with industry and academia, and work with other jurisdictions to identify and implement physical and digital infrastructure. The strategy also sought to identify policy and regulation that supports these outcomes, including the need to engage with and educate the public (TfNSW 2018b: 60–61). The TfNSW (2018a) *Connected and Automated Vehicles Plan* provides this further detail.

Evaluation

Table 3 shows the evaluation of the 'Transport platform' innovation domain. Of the evaluation criteria that suggest positive impacts, the scalability of the policy—from a niche market to a mobility regime—and the potential for innovation are predominantly moderate to very high for all sub-innovations where covered by policy documents. Only the Victorian *Plan Melbourne* (DELWP 2017) was allocated low scores for these two criteria. The low scores reflected the lack of any detail about AVs and demand-responsive transport beyond high-level one-line statements, which made it difficult to see how metrics like scalability and innovation potential could be achieved.

Most policies for this sub-domain offer moderate to very high potential for disruption of private car ownership, while minimising disruption to public transport and active transport. This is as a result of the strong focus on policies designed to facilitate shared transport modes rather than support private AVs, although there are no policies directed to countering AVs—however, parking restrictions already being applied might achieve this outcome. Some strategies take a step further than facilitation by proactively trialling shared AVs and public transport, and also investing in them. In addition, some policies seek to address issues of data availability and protection for MaaS activity, by first capitalising on government-controlled data and then looking to work collaboratively with the private sector providers. As yet there are only limited parking policies and no urban development policies that could help support shared AVs: this is an area that urban land-use planners could get active in. Infrastructure Victoria identified the need for parking controls to be adapted for the AV era in a manner that builds on recent innovations ending minimum bay requirements, and discussed the need for drop-off points and congestion charges in inner Melbourne.

The 'extent of impacts' criteria score less well in terms of 'extent of impact on policy debate, reflective of the novelty of these innovations and limited time for proposed ideas to be referenced by other plans. This applies particularly to 'extent of impact to date' criteria, again because of the insufficient passage of time to see major application to date. As yet the potential of these policies to disrupt the private car ownership model is very low or low, as these innovations are either still in the research phase or only recently introduced to the market.

For Table 3 and subsequent evaluation tables, the colour codes assigned to each criteria are consistent with those used in Table 2 above. The coloured cells evaluate the performance of strategies referenced in Table 1 above. Each strategy referencing a sub-topic (such as Mobility as a Service), within a particular domain of innovation—for example, 'Transport platform'—is depicted with a tick ( ) in Table 1 (see above).

Table 3: Policy document evaluation: Transport platform

Criteria / Type of innovation	Mobility as a Service (MaaS)			Ride-hailing and car-sharing			Micromobility		Autonomous vehicles			
Ability to operationalise												
Scalability: from 'niche' market to mobility 'regime'												
Potential for innovation												
Access/inclusion: affordable, safe, legible												
Potential for disruption of private car ownership and use												
Minimal disruption to PT												
Minimal disruption to AT												
Impact on policy debate to date												
Extent of impact to date												
Disruption of private car ownership and use												
Transferability?												

Note: PT = public transport; AT = active transport. *= Very low (1),* *= Low (2),* *= Slight (3),* *= Moderate (4),* *= Very high (5).*
Sources: DTMR (2018), DPLH (2018), DELWP (2017); DoT (2019a), DoT (2019b), TfNSW (2018a), TfNSW (2018b), TfNSW (2018c).

4.1.2 Innovation Domain: Influencing travel behaviour

The majority of state transport and land-use strategies seek to influence travel behaviour by managing travel demand and increasing use of more environmentally benign modes . Looking at the sub-topics of lessening car dependency, addressing declining public transport usage and encouraging telecommuting the following are observed.

Lessening car dependency

Lessening car dependency is an objective favoured by most of the land-use and transport strategies. The *Perth and Peel @ 3.5 million* strategy (DPLH 2018: 13) argued that car dependency will be reduced by 'greater provision and use of public transport, such as through the METRONET program'. Victoria's *Plan Melbourne* (DELWP 2017: 62) argued that increases in public and active travel are required to reduce car reliance, which can be achieved by creating an integrated public transport network and ensuring 'land use and transport … support convenient local trips'. Melbourne's five-year strategic plan, *Simple, connected journeys* (DoT 2019b) calls for construction of safe cycling and pedestrian infrastructure, and more pedestrian crossings to connect communities. This requirement is also recognised by Sydney's *Future transport strategy 2056*, which noted that higher rates of walking and cycling are predicated on improvements to environmental conditions, such as shaded footpaths, separated cycling paths and safe pedestrian crossings. The strategy noted that undercover bike storage is already being provided at railway stations.

Addressing declining public transport usage

Addressing declining public transport usage is not explicitly recognised by the policy documents as such. However, the majority of land-use and transport documents identify measures to increase travel by this mode. A common theme entails network expansion, via funded programs such as Perth's METRONET, described in *Perth and Peel @ 3.5 million* (DTMR 2018), and Melbourne's Metro Tunnel and airport rail line set out in the *Simple, connected journeys* plan (DoT 2019b).

Another way to increase public transport patronage is to improve trip reliability and speed times via a dedicated right-of-way, as suggested for Melbourne's buses and trams by *Plan Melbourne* and Sydney's buses by the *Future transport strategy*. Although social equity considerations underpin the commitment to inclusive design of stops, stations and vehicles by strategies such as Sydney's *Future transport strategy* and *Plan Melbourne*, these actions will also serve to increase ridership. Other measures include network integration and signalling to increase throughput and enable higher service frequencies, as recommended by *Plan Melbourne*.

Encouraging telecommuting

Encouraging telecommuting to reduce travel demand is identified by DTMR (2018) in *Perth and Peel @ 3.5 million*, which suggested that advances in ICT are likely to increase teleworking and tele-service delivery. The strategy estimated that a quarter of Australian workers already do some of their work from home. Sydney's *Future transport strategy* (TfNSW 2018b: 64) sees a growing role for automated first-mile and last-mile freight deliveries, and recommends the state 'investigate the role drones may play in first and last-mile freight delivery'.

Evaluation

Table 4 depicts the evaluation of the 'Influencing travel behaviour' innovation domain.

The scalability of an innovation from 'market niche' to 'mobility regime' is an evaluation criterion against which all of the reviewed strategies perform well. This scalability potential poses little risk to the public transport business model, hence most of the policies also perform well against the criterion 'Minimal disruption to public transport'.

This reflects the way the documents seek to alter travel behaviour via improvements to the size and frequency of the public transport network, while increasing the system's reach through improvements to active transport infrastructure. One exception is the growth of telecommuting, an innovation identified in the DTMR (2018) *Perth and Peel @ 3.5 Million Strategy*. This arises as former public transport commuters—who form the backbone of Australia's high-capacity transit networks—reduce their day-to-day travel. This is not necessarily a 'bad' outcome—lessening travel demand reduces transport energy consumption and fewer peak-hour travellers remove strains on overstretched systems.

A substantive issue confronting the policies is whether they can leverage the potential for innovation and market scalability into substantive outcomes capable of disrupting the 'system' of automobility (Urry 2004). So far, none of the travel behaviour policy introduced into the Australian context has performed well against the criterion 'Disruption of private car ownership and use to date'. To some extent, this reflects the long timeframes associated with policy formation, implementation and the resulting behaviour change.

A fairer critique is to recognise that while strategies tend to recognise that more support is required to increase active travel and public transport usage, they are silent on the inherent contradiction between supporting such measures while simultaneously embarking on ambitious road-building programs. These programs not only divert finite resources available to the transport sector, they also increase the competitiveness of private car travel by increasing capacity —and, at least temporarily—reducing travel times between far-flung metropolitan regions. The strategies also appear to under-appreciate the extent to which automobility is entrenched in our cities and urban culture.

The transferability of the proposed innovations varies considerably. Many strategies outline steps that can be emulated by authorities working in different jurisdictions because of similarities in variables such as urban form and function. *Plan Melbourne* achieves the highest score against this criterion for the sub-topic 'Addressing

declining public transport usage' as measures such as dedicated lanes for public transport, network expansion and universal access are measures that can be implemented in most cities, subject to funding and regulatory reform. However, the recommendation by the NSW *Future transport strategy* to 'investigate road network access charges for commercial users' (TfNSW 2018b: 140) is less readily transferable, given institutional barriers such as the established norm of untolled roads prevalent in jurisdictions such as WA.

Table 4: Policy document evaluation: Influencing travel behaviour

Criteria / Type of innovation	Lessening car dependency						Addressing declining public transport usage					Encouraging telecommuting	
Ability to operationalise													
Scalability: from 'niche' market to mobility 'regime'													
Potential for innovation													
Access/inclusion: affordable, safe, legible													
Potential for disruption of private car ownership													
Minimal disruption to PT													
Minimal disruption to AT													
Impact on policy debate to date													
Extent of impact to date													
Disruption of private car ownership and use													
Transferability?													

Note: PT = public transport; AT = active transport. = *Very low (1),* = *Low (2),* = *Slight (3),* = *Moderate (4),* = *Very high (5).*
Sources: DTMR (2018), DPLH (2018), DELWP (2017); DoT (2019a), DoT (2019b), TfNSW (2018a), TfNSW (2018b), TfNSW (2018c).

4.1.3 Innovation domain: Urban structures

Changing the structure of metropolitan cities is a common theme across the land-use planning policies of all three states, which reflects concerns about the negative externalities associated with car-centric suburban 'sprawl'. The following observations were made about the two sub-topics in this domain of innovation.

High-value local activity centres to lessen commuting

This is a sub-topic of innovation, entailing a considerable amount of policy deliberation.

In WA, the *Perth and Peel @ 3.5 million strategy* (DPLH 2018: 9) articulated a plan for a 'connected city' with a strong CBD and activity centres 'designed to be attractive, accessible, compact, vibrant, pedestrian and cycling-friendly environments that have high quality public transport and road linkages'. These activity centres will provide residential development, employment and services in a high amenity environment.

In Victoria, *Plan Melbourne* (DELWP 2017: 10) sought to create a '20 minute city' inclusive of 'accessible, safe and attractive local areas where people can access most of their everyday needs within a 20-minute walk, cycle or local public transport trip'. The strategy recognises the practical limits to this philosophy, noting that 'due to the specialised and diverse nature of work, many people will still need to travel outside of this 20-minute neighbourhood for their jobs' (2017: 10). As such, the plan recognises the need to support the ongoing development of activity centres that 'provide a diverse range of jobs, activities and housing for regional catchments that are well served by public transport' (2017: 15). The plan also identifies 'major urban renewal precincts' that 'take advantage of underutilised land close to jobs, services and public transport infrastructure, to provide new housing, jobs and services' (2017: 16). The *Movement and place in Victoria strategy* (DoT 2019a) complements *Plan Melbourne* by identifying roads suitable for provision of public transport, active transport and urban redevelopment. Along such roads the 'place function' is seen to exceed the importance of the 'movement function'.

In NSW, the *Future transport strategy* (TfNSW 2018b) unveiled a vision for Greater Sydney as a metropolis of three cities. This vision could support the development of a so-called 'thirty-minute city' enabling most people to access jobs and services by public transport within 30 minutes travel time, ensuring residents enjoy a high quality of life. The document also identified a hierarchy of three corridors, including city and centre-servicing corridors, that included public and active transport infrastructure, and were suitable for higher-density urban redevelopment.

There is an inherent contradiction in an approach to changing urban structures that supports activity centres, corridors and inner-city renewal while simultaneously permitting significant outer-suburban greenfield developments; achieving the former is made more difficult by continuing with the latter. This issue is particularly relevant to Perth, a city in which greenfield development still accounts for 66 per cent of new development (Department of Planning 2018: 13). The internal contradiction of spatial planning objectives is least apparent for Sydney because of the much larger share of development in existing urban areas, including high-density activity centres.

There also appears to be an under-appreciation of the potential for urban infill to create oppressive 'urban heat islands' that can discourage active transport and dissuade potential residents from selecting activity centres and urban renewal areas as places in which to reside. This is an issue that can only grow in importance because of anthropogenic climate change, and is particularly relevant to places such as Western Sydney.

Improving public transport on the urban fringe

Improving public transport on the urban fringe is a theme taken up in Victoria by two policy documents: *Plan Melbourne* (DELWP 2017) and *Simple, connected journeys* (DoT 2019).

Plan Melbourne recognises the importance of better sequencing of public transport infrastructure provision with urban development, and ensuring that more of this growth occurs along the catchments of public transport routes. The strategy states that 'the sequencing of development in Melbourne's growth areas will be improved along with increasing the diversity and density of development along the PPTN (priority public transport networks) and near stations. This helps enable the timely delivery of services' (DELWP 2017: 71).

Simple, connected journeys (DoT 2019: 12) calls for 'introducing better bus services for growing communities to connect people to stations and other places' and recognised the need for 'building commuter car parks to encourage more people to take the train and un-clog local streets'.

These two strategies do not critique the ability of linear rail and bus extensions into peri-urban areas with poor public transport accessibility to shift travel behaviour to more sustainable modes. While growth areas must have timely provision of new public transport infrastructure to avoid car-centric travel habits from becoming entrenched, more scrutiny of rezoning and subdivision proposals appears warranted. This could be achieved by applying more robust locational criteria that includes public transport accessibility measures.

Evaluation

Table 5 show the evaluation of the 'Urban structures' innovation domain, and should be read in conjunction with Table 1.

The strategies are all complementary to public and active transport in terms of planning for additional and better quality infrastructure—including growth areas and activity centres—and directing economic and population growth to areas well served by sustainable transportation infrastructure. As such, they all achieve high scores for the evaluation criteria 'Minimal disruption to public transport' and 'Minimal disruption to active transport'. These solutions are also highly scalable which accounts for the high scores they are allocated for the criterion of 'Scalability: from "niche" market to mobility "regime"'.

However, 'Ability to operationalise' poses a more significant challenge for some of the strategies, which reflects their low scores. For example, the outcomes sought in *Plan Melbourne* are framed as high-level aspirational statements, without clarity as to how the transition will be managed. To some extent this limitation is also true for the land use and transport plans in both *Perth @ 3.5 million strategies* (DPLH 2018; DTMR 2018). By contrast, Melbourne's *Movement and place strategy* (DoT 2019) provides clear criteria distinguishing the place and movement qualities of a road to guide land-use and transport planners. This lends itself to operationalisation by the responsible authorities. Sydney's *Future transport strategy* (TfNSW 2018) embraces a logical approach of 'stepping' down from
high-level vision statements and policy ideas to more detailed plans capable of implementation. For example, the conceptual tool of the 'transport corridor hierarchy' is applied to specific plans prepared for each district of the Sydney metropolitan region.

Institutional barriers are a common dilemma for all strategic plans seeking to implement change. This source of social inertia includes:

- the operation of corporate 'silos' in state government
- the criteria guiding capital allocation by the finance and property development sectors
- aspirations for home ownership
- the entrenched car culture.

The barriers do not appear to be acknowledged. The private car ownership model remains firmly entrenched in all but a few inner-urban areas of our largest cities. This reality is reflected in the low scores the evaluated plans received against the related criteria 'Extent of impact to date' and 'Disruption of private car ownership and use'.

Table 5: Policy document evaluation: Urban structure

Criteria / Type of innovation	High-value local activity centres to lessen commuting					Improving PT on the urban fringe	
Ability to operationalise							
Scalability: from 'niche' market to mobility 'regime'							
Potential for innovation							
Access/inclusion: affordable, safe, legible							
Potential for disruption of private car ownership an use							
Minimal disruption to PT							
Minimal disruption to AT							
Impact on policy debate to date							
Extent of impact to date							
Disruption of private car ownership and use							
Transferability?							

Note: PT = public transport; AT = active transport. = *Very low (1),* = *Low (2),* = *Slight (3),* = *Moderate (4),* = *Very high (5).*
Sources: DTMR (2018), DPLH (2018), DELWP (2017); DoT (2019a), DoT (2019b), TfNSW (2018a), TfNSW (2018b), TfNSW (2018c).

4.1.4 Innovation domain: Climate change and pricing

Climate change is widely recognised as an issue of concern, and several strategies recognise the role EVs will play in climate change mitigation. However, NSW is currently the only state to undertake serious research and commit to substantive actions to commence the required transition. NSW is also without peer in the published strategic plans we reviewed when it comes to discussing road pricing—a measure that may prove imperative if aligned with policies supporting shared use of clean vehicles, thus maximising mitigation efforts.

Electric vehicles

Electric vehicles utilise energy more efficiently than conventional engines, and their operation can be entirely carbon free—subject to the supporting electricity grid being powered by zero-carbon sources. As such, they represent a viable means to achieve rapid transport-sector decarbonisation. This technology is referenced by four strategies.

The WA *Perth and Peel @ 3.5 million* (DPLH 2018) strategy recognises that 'the increasing use of electric bikes will take more cyclists longer distances, faster, for less effort'. This observation is made in the context of proposals to expand cycling networks to improve accessibility of activity centres and public transport, and provide end-of-trip facilities at train stations.

Victoria's *Simple, connected journeys* (DoT 2019) lists 'supporting the uptake of electric vehicles' as one of the state's initiatives, but without providing more detail.

NSW, according to the *Future transport strategy*, supports the EV transition by:

- Trialling the State's first automated, electric passenger shuttle at Sydney Olympic Park in partnership with industry
- Recommending that 'conveniently located charging stations' be included into apartment designs under the Department of Planning and Environment's Apartment Design Guide.
- Lowering motor vehicle registration taxes for EV and hybrids.

The strategy also states that NSW will prepare an Electric and Hybrid Vehicle Plan (TfNSW 2018b: 66). This led to the release in January 2019 of the *NSW electric and hybrid vehicle plan* (2019), which contains a number of specific new actions beyond those already under way. The actions relate to vehicle availability, charging points and customer information. Some key actions include:

- establishing a 10 per cent EV target for the NSW Government passenger fleet
- co-investing in charging infrastructure on regional roads and urban car parks
- ensuring new buildings provide EV charging.

The plan also commits to an EV bus trial and seeks to facilitate trials with car-share and ride-hailing operators.

Road pricing

Road pricing is a theme that is only taken up in NSW. The state's *Future transport strategy* commits to investigating 'road network access charges for commercial users with revenue hypothecated for related network improvements' (TfNSW 2018b: 140). This would provide a clear price signal favouring shared rides for today's ride-hailing operators and future fleets of shared, autonomous, electric vehicles (SAEVS).

Parking pricing

Parking pricing is discussed by the *Connected and automated vehicles plan* prepared by the NSW Government in 2019.

Evaluation

The evaluation of the 'Climate change and pricing' innovation domain is shown in Table 6, which should be read in conjunction with Table 1.

The sub-innovations of EVs and road pricing achieve high scores for the evaluation criteria of 'Scalability: from "niche" market to mobility "regime"' and 'Potential for innovation'. The measures outlined by the policies do not threaten to disrupt public or active transport and thus achieve good scores for the criteria 'Minimal disruption to public transport' and 'Minimal disruption to active transport'.

The policies have diverging scores for the evaluation criterion 'Potential for disruption of private car ownership and use'. The *Future transport strategy* (TfNSW 2018b) achieves a moderate score for this criterion in the sub-innovation categories electric vehicles and road pricing because of their comprehensive provisions for sustainable transport infrastructure and land-use planning. NSW also seeks to steer the impending mobility transition by:

- increasing the level of support for active travel and proven high-capacity transit modes—including the development of new metro lines, bus lanes and light rail
- encouraging innovation in new shared-use applications such as electric and autonomous buses—including on-demand models in areas of low trip density
- encouraging MaaS platforms supportive of modes such as ride-hailing and car-sharing.

Although the *NSW electric and hybrid vehicle plan* (TfNSW 2018c) has low potential to disrupt the private car ownership model because of its narrower focus—as it is not specifically charged with changing travel mode share—the plan is adopted under the framework of the more holistic *Future transport strategy*, and outlines practical measures to remove impediments to EVs, such as increasing charging infrastructure. This will be required under both a private and shared-ownership model. The plan also recognises the important role that buses and shared mobility applications will play in the mobility transition. NSW stands out as the clear leader among the three states investigated by this report in terms of undertaking the necessary research and stakeholder collaboration, as well as for committing to specific actions that support the electrification of transport.

Although Victoria's *Simple, connected journeys* (DoT 2019) states it will support EVs as a policy objective, the document does not discuss how the private ownership model might be disrupted, or the risk that increasingly affordable electric cars—in terms of operating and purchase cost—might further entrench individual car ownership. This will be a distinct possibility by the second half of the decade considering design attributes such as energy efficiency and minimal moving parts. The other significant variable concerns the achievement of global economies of scale in battery production facilities, and innovation learning curves, both of which are likely to result in significant price reductions for batteries.

The WA *Perth and Peel @ 3.5 million* (DPLH 2018) strategy makes a useful contribution to the consideration of electric bikes, an innovation that could disrupt car ownership subject to adequate cycling and bike-parking infrastructure and integration with high-frequency public transport networks. However, considering the challenges faced by Perth's highly dispersed settlement pattern and poor public transport accessibility, this innovation in isolation is unlikely to make serious inroads capable of disrupting the entrenched car ownership model. Nevertheless, it is a technical innovation worthy of further research because of its lower costs (financial and environmental) compared to larger electric vehicles, as well as the ability to provide independent mobility to those without a driver's licence. A significant consideration concerns the design criteria for bike paths, which may need wider and straighter paths because of faster speeds and growing trip volumes. (This assumes that cycling becomes increasingly popular because of the superior comfort and range of electric bikes compared to their conventional counterparts.)

The assessed documents all scored poorly for the criterion 'Extent of impact to date'. This may be reflective of the inadequate time that has elapsed since the release of these plans. However, in Norway, where market intervention has greatly reduced the purchase price of electric cars and the policy has been complemented by provision of fast-charging stations, consumer sales have immediately soared in response (Rietmann and Theo 2019). The policies also scored poorly under the criterion 'Disruption of private car ownership and use'. This more reasonably reflects the inadequate time between release of the plans and any observable change on account of the length of time associated with mobility transitions.

Table 6: Policy document evaluation: Climate change and pricing

Criteria / Type of innovation	Electric vehicles				Road pricing
Ability to operationalise					
Scalability: from 'niche' market to mobility 'regime'					
Potential for innovation					
Access/inclusion: affordable, safe, legible					
Potential for disruption of private car ownership and use					
Minimal disruption to PT					
Minimal disruption to AT					
Impact on policy debate to date					
Extent of impact to date					
Disruption of private car ownership and use					
Transferability?					

Note: PT = public transport; AT = active transport. *= Very low (1),* *= Low (2),* *= Slight (3),* *= Moderate (4),* *= Very high (5).*
Sources: DTMR (2018), DPLH (2018), DELWP (2017); DoT (2019a), DoT (2019b), TfNSW (2018a), TfNSW (2018b), TfNSW (2018c).

4.1.5 Innovation domain: Infrastructure procurement

The large capital outlays associated with building high-capacity public-transport infrastructure have prompted cities to investigate alternative funding schemes.

Value capture for funding projects

Value capture for funding projects is a mechanism discussed by the NSW *Future transport strategy* (TfNSW 2018b), which states: 'The NSW Government will continue to assess opportunities for value sharing as investment projects are developed' (2018b: 141). It further commits to 'identify balanced beneficiary models including value sharing and developer contributions aligned with improved land-use planning' (TfNSW 2018b: 141). The strategy seeks to 'identify supplementary sources of revenue across the portfolio including commercial revenues through internal advertising, commercial leasing and airspace use, particularly at new interchanges' (TfNSW 2018b: 141).

Value capture is also mentioned by Victoria's *Plan Melbourne* (DELWP 2017) though it is restricted to the context of affordable housing provision in urban renewal areas benefiting from land-value uplift following rezoning. This is an important social equity consideration and indirectly relates to transport sector innovation in terms of ensuring 'key workers' and other lower income groups can reside in transit-friendly precincts such as urban renewal areas. The plan notes: 'There is scope to capture some of the value created by the rezoning process for policy priorities such as social and affordable housing' (DELWP 2017: 56) and commits to reforming the planning system to achieve these outcomes.

Evaluation

The evaluation of the 'Infrastructure procurement' innovation domain is shown in Table 7, which should be read in conjunction with Table 1. Sydney's *Future transport strategy* (TfNSW 2018b) and *Plan Melbourne* (DELWP 2017) are assessed for the sub-topic 'Value capture for funding projects'.

Both policies score well for the evaluation criteria 'Minimal disruption to public transport' and 'Minimal disruption to active transport'. They also show potential for scalability and innovation and score well for the associated criteria 'Scalability from "niche" market to mobility "regime"' and 'Potential for innovation'. *Plan Melbourne* calls for value capture to be used to finance affordable housing in urban redevelopment areas and therefore gets a high score for 'Access/inclusion: affordable, safe, legible'.

The two strategies score very differently for the criterion 'Ability to operationalise'. *Plan Melbourne* gets a high score due to the specific measures outlined and a commitment to reform the planning system, whereas the NSW strategy *Future transport strategy* only agrees to assess opportunities and identify models for value capture. In terms of the criteria 'Extent of impact to date' and 'Disruption of private car ownership and use', the two policies are awarded the lowest score, which reflects the lack of any measured impact—as no action has been implemented to date.

To sum up, neither state has published a lot of work in this area. However, Victoria is at least committing to a future reform of its planning system, while NSW is only in the exploring options phase. In Western Australia, the first phase of recognising a future need to investigate value capture has yet to be taken.

Table 7: Policy document evaluation: Infrastructure procurement

Criteria / Type of innovation	Value capture for funding projects	
Ability to operationalise		
Scalability: from 'niche' market to mobility 'regime'		
Potential for innovation		
Access/inclusion: affordable, safe, legible		
Potential for disruption of private car ownership and use		
Minimal disruption to PT		
Minimal disruption to AT		
Impact on policy debate to date		
Extent of impact to date		
Disruption of private car ownership and use		
Transferability?		

Note: PT = public transport; AT = active transport. *= Very low (1),* *= Low (2),* *= Slight (3),* *= Moderate (4),* *= Very high (5).*
Sources: DTMR (2018), DPLH (2018), DELWP (2017); DoT (2019a), DoT (2019b), TfNSW (2018a), TfNSW (2018b), TfNSW (2018c).

4.2 Emerging policy interests

Section 4.1 reviewed recent policy documents from NSW, WA and Victoria that are available in the public domain. In order to get a sense of the emerging considerations for transport policy innovation, we include a review of selected Commonwealth and state documents that give an indication of emerging policy interests. Two of the publications are from Infrastructure Australia (IA). The third report is from Infrastructure Victoria (IV), a Victorian Government agency with a similar role to IA. The fourth paper is a discussion paper from the WA road-building authority, Main Roads WA (MRWA). As NSW is already at an 'action plan' level of implementation it was not included in this analysis. Documents analysed were those primarily identified by the PRG. An overview of policy content by document by innovation domains is shown in Table 8.

Table 8: Australian emerging policy interests

Domains of innovation	Sub-topic	An assessment of Australia's future infrastructure needs: the Australian infrastructure audit (IA 2019)	Outer urban public transport: improving accessibility in low-density areas (IA 2018b)	Advice on automated and zero emissions vehicles (IV 2018)	Automated vehicles. Are we ready? Internal report on potential implications for Main Roads WA (DTMR 2015)
Transport platform	Mobility as a Service (MaaS)	■	■	■	■
	Ride-hailing apps and car-sharing	■	■		
	Micro-mobility		■		
	Autonomous vehicles	■	■		
Influencing travel Behaviour	Lessening car dependency	■	■		■
	Addressing declining public transport usage			■	■
	Encouraging telecommuting / online shopping				■
Urban structures	High-value local activity centres to lessen commuting	■	■	■	
	Improving public transport on the urban fringe	■			
Climate change and pricing	Electric vehicles	■		■	
	Road pricing	■		■	
	Parking pricing			■	
Infrastructure procurement	Value capture for funding projects	■	■		

Note: PT = public transport; AT = active transport.

Sources: IA (2019), IA (2018b), IV (2018), DTMR (2015).

4.2.1 Innovation domain: Transport platform

Each sub-topic is reviewed in turn.

Mobility as a Service

Mobility as a Service is tackled in all four documents.

The *Australian infrastructure audit* (IA 2019) recognised the potential benefits of MaaS for both travellers and public transport providers. It argued that 'a well-designed and implemented MaaS scheme can save consumers costs and provide an alternative to personal car ownership' (IA 2019: 280). The audit further claimed:

MaaS could be a useful tool for public transport providers that are increasingly looking towards on-demand and multimodal transport solutions to help expand the reach of their public transport networks, and fulfil the first- and last-mile transport needs of passengers. The impacts of MaaS could be accelerated and multiplied when coupled with other emerging technologies, particularly automated vehicles. (2019: 280).

The paper observed that private sector actors had thus far been incapable of effective collaboration to create a MaaS system, and claimed this was due to institutional barriers or the absence of a 'single common framework' (IA 2019: 280). The Queensland Government is cited as an example of an authority that has established a MaaS project office.

Outer urban public transport (IA 2018b) stressed the high operating costs and low public transport mode share in Australian outer suburbs, and the potential of MaaS to address this. It therefore called for Australian governments to 'embrace technological innovation in transport, working with third party operators to improve user experience' (IA 2018b: 8). Specific measures recommended by IA include integrated ticketing and open access data to enable these third parties to provide timetable information. These benefits would flow from adopting a more 'outcomes-based regulatory approach' (IA 2018b: 8).

The importance of open data is also recognised by the *Advice on automated and zero emissions vehicles* report (IV 2018). It called for 'the availability of open, real-time information on government-owned transport system data and established principles for data sharing between government and commercial transport service providers' (IV 2018: 60). The report contended that better transport services enabled by MaaS would bring consumers benefits, even prior to the advent of AV technology, and further argued that: 'Open data is also a likely precursor to effective integration of automated vehicles within the broader transport system' (IV 2018: 61).

Automated vehicles: are we ready? (Department of Main Roads [DMR] 2015) envisaged the future use of AVs on a shared subscription basis. The report anticipated benefits in terms of reduced vehicle ownership. Greater efficiencies would be achieved by fleets as opposed to individually owned cars, which sit idle most of the day. Consumers prepared to share a ride would benefit from cheaper rides.

Ride-hailing apps and car-sharing

The *Australian infrastructure audit* (IA 2019) reflected on the increasing difficulty encountered by authorities responsible for planning and operating infrastructure in a period of rapid change, noting that ride-hailing had more than trebled since 2015. The report recognised the risk of rising traffic congestion if riders desert space-efficient public transport due to the increasing affordability and availability of ride-hailing. There was also a risk that people with disabilities may not benefit from the availability of such point-to-point transport, as ride-hailing firms are not subject to the same accessibility legislation and subsidy regime as taxis.

According to *Outer urban public transport* (IA 2018b), public transport should be accessible to ride-hailing. The report saw ride-hailing as ideally placed to serve low-density areas with low demand, such as outer suburbs. The publication went so far as to urge ride-hailing be expanded and become the 'basis for public transport in outer urban settings' (IA 2018b: 57). The example of a partnership between Transport for Canberra and Uber was raised. This was a trial that aimed to increase the reach of Canberra's late-night bus service during the summer months of 2016–2018. The two entities agreed to a $10 subsidy for rides emanating from bus stops to surrounding suburban areas to provide an affordable means to address the last-mile public transport accessibility problem.

Micro-mobility

Outer Urban Public Transport (IA 2018b) recognised the potential for active transport and emerging forms of shared micro-mobility to improve access to suburban train stations. The report therefore called on responsible authorities to improve active transport infrastructure in public transport catchments, and for train stations to have bike-parking facilities. It stated that 'governments should support, and consider providing, on-demand bike services (such as e-bikes and bike-share) at stations. This will allow passengers who do not own a bike, or are unable to bring their bike on public transport, to extend how far they can travel once they end their public transport trip' (IA 2018b: 68). The report made the recommendation for 'providing car-share, e-bike and bike-share facilities' (IA 2018b: 68).

Autonomous vehicles

AVs are an emerging technology discussed by all four documents: IV and MRWA are specifically about the technology, while the IA reports discuss it as a component of transport innovation. Their discussion of AVs as a component of transport innovation is discussed and evaluated.

The *Australian infrastructure audit* (IA 2019) anticipated the emergence of AV technology in coming years, while acknowledging uncertainty of technology development timelines. The document discussed potential benefits and risks:

- **Benefits:** improvements to road safety, lane capacity and affordability of ride-hailing.
- **Risks:** rising congestion due to mode-shift from public transport, competition for kerb spaces due to passenger pick-up/drop off, more urban sprawl if commuters tempted to move further out.

It also noted that AVs needed to learn how to share road space with vulnerable users, including people travelling by active transport. The report pointed out that the significant potential benefits from AV technology would only be realised if institutional impediments were removed, including the estimated 716 legislative and regulatory barriers to AVs:

> There is a lack of appropriate regulation, trials and physical infrastructure to enable the use of many cooperative and autonomous vehicle features. Without action, the benefits offered by cooperative and autonomous vehicles will be missed. (IA 2019: 288)

The leadership shown by Queensland was acknowledged, as demonstrated by an ambitious on-road trial of CAVs including 500 fleet and private vehicles. The project was administered by Queensland's Department of Transport and Main Roads (TMR) and named the Cooperative and Automated Vehicle Initiative (CAVI).

Although the risks to scheduled public transport from low-cost autonomous ride-hailing is acknowledged by *Outer urban public transport* (IA 2018b), the report nevertheless urged state and territory governments to 'embrace new transport modes, such as on-demand services, which are well suited to low-density areas'. It called on responsible authorities to 'develop coordinated whole-of-government implementation and communication strategies to support the adoption of connected and automated vehicles, including the use of pilots and trials' (IA 2018b: 6). This call was made due to the potential for AV to dramatically reduce bus-operating costs in the outer urban areas of Australia, and noted that buses are the 'workhorses' of our outer suburbs. The report argued that the impacts of this disruptive technology on public transport will be determined by pricing and regulation, suggestive of our ability to guide the coming socio-technical transition to benefit our urban communities.

Evaluation

The evaluation of the 'Transport platform' innovation domain is presented below (Table 9), based on the emerging policy interests above (Table 8).

The evaluation criteria 'Scalability: from "niche" market to mobility "regime"' and 'Potential for innovation' both achieve a predominantly moderate to very high score for all sub-topics addressed by the reports reviewed in this section. Ride-hailing is a type of innovation that has already demonstrated this potential for both market scalability and technical innovation. However, the other sub-topics display similar potential for growth and technical development. Such growth is enabled by the near ubiquitous portable technology of the smartphone.

However, on the criteria of 'Ability to operationalise' only the IV (2018) report *Advice on automated and zero emissions vehicles* achieves a moderate score for the MaaS sub-topic. This is reflective of its innovative process of identifying so-called 'triggers' or pre-conditions for taking supportive actions to enable an emerging innovation. By contrast, the MRWA discussion paper's low score reflected the lack of any detail on how future use of AVs as a shared service would be achieved. For the sub-topic of 'Ride-hailing apps and car-sharing' only the IA (2018b) report *Outer urban public transport* achieved a moderate score for this criterion as specifically identified the need for ride-hailing to be integrated into public transport systems. However, for the sub-topics 'micro-mobility' and 'autonomous vehicles' the assessed reports achieved a lower score suggesting further policy development is required to support this mobility transition.

In terms of the criteria 'Impact on policy to date' only the sub-topic 'ride-hailing and car-sharing' achieves a moderate score for the two policies assessed, reflective of the growing significance of this new transportation mode and its discussion in emerging policy. However, the documents covering the sub-topics relating to MaaS, micro-mobility and AVs achieved scores ranging from slight to very low, as these sectors have yet to have any significant impact on the Australian policy environment.

The reports tended to score slight to low for the criterion 'Extent of impact to date'. Only IA's *Infrastructure audit* (2019) received a moderate score for the sub-topic of 'Ride-hailing apps and car-sharing' as it recognised pertinent challenges, such as potentially adverse impact on public transport and the need for ride-hailing to be socially inclusive. The papers also ranged from slight to very low against the criteria 'Disruption of private car ownership and use'. The growing population of privately owned cars attests to the lack of any substantive disruption to this entrenched model in Australia to date. Somewhat more encouragingly, the transferability of ideas and initiatives discussed by the reports was mostly moderate to very high, raising the possibility that institutional learning and policy innovation may progress through a productive 'cross-fertilisation' across jurisdictions.

Table 9: Policy document evaluation: Transport platform

Criteria / Type of innovation	Mobility as a Service				Ride-hailing apps and car-sharing		Micromobility	Autonomous vehicles	
Ability to operationalise									
Scalability: from 'niche' market to mobility 'regime'									
Potential for innovation									
Access/inclusion: affordable, safe, legible									
Potential for disruption of private car ownership									
Minimal disruption to public transport									
Minimal disruption to AT									
Impact on policy debate to date									
Extent of impact to date									
Disruption of private car ownership and use									
Transferability?									

Note: PT = public transport; AT = active transport. *= Very low (1),* *= Low (2),* *= Slight (3),* *= Moderate (4),* *= Very high (5).*
Sources: IA (2019), IA (2018b), IV (2018), DTMR (2015).

4.2.2 Innovation domain: Influencing travel behaviour

Lessening car dependency

The *Australian infrastructure audit* (IA 2019: 279) notes that 'the growing sharing economy is making car ownership less attractive'. The report cited figures showing decreasing drivers' licence possession among young people in Victoria as evidence of this trend, but added a caveat: 'The opportunity for reduced car ownership may be limited to inner-city areas, where access to public transport is better and the take up of ride and car sharing is most prevalent' (IA 2019: 281).

The audit reflects on the uncertainty confronting decision-makers: are ride-hailing and car-sharing likely to increase or decrease car dependency? This presents plausible yet diverging scenarios. Shared use of ride-hailing as a first-mile or last-mile public transport accessibility tool would take cars off the street. However, it would also lure existing public transport patrons to on-demand mobility alternatives that would further increase reliance on cars, with governments left to bear the cost of thinly patronised systems used by the remaining 'captive users' who lacked access to the new shared mobility options.

Two reports tackle the sub-topic of lessening car dependency by identifying non-recreational cycling as the means to innovate. *Outer urban public transport* (IA 2018b) addresses the need to provide bike parking and safe cycling access to public transport hubs. Recommendation 4 of the report states:

> State, territory and local governments should improve the physical integration of the public transport network with private, active and emerging transport modes by:
>
> - improving access for private transport to interchanges, including providing additional car parking where appropriate, drop-off facilities, as well as bike storage
> - providing car-share, e-bike and bike-share facilities at major interchanges to support a broader range of end-journeys
> - integrating active transport, including walking and cycling, through dedicated infrastructure, improved lighting and all-weather protection. (IA 2018: 68).

The DTMR (2015) report *Automated vehicles: are we ready?* anticipated that AVs will bring significant benefits for vulnerable road users, including pedestrians and cyclists. These improvements are expected due to a number of factors:

- The disappearance of on-street parking bays will create additional space for active transport (estimated for 2035–2045).
- The road environment will become less hazardous to pedestrians and cyclists, since AVs would take evasive manoeuvres around them.
- The reduction in the number and width of traffic lanes will improve amenity for those using active travel.

Addressing declining public transport usage

Advice on automated and zero emissions vehicles (IV 2018) models a number of different scenarios assuming different ownership modes, technologies and rates of change. Each scenario predicted much higher levels of public transport use than today, in part reflective of the high rate of population growth forecast for Victoria. Even their 'private drive' scenario, in which all AVs are privately owned, sees more than twice as many public transport patrons than today. The shared-ownership scenario predicts the highest rate of public transport usage by 2046 (four times today's figures), in part due to the higher perceived—and actual—cost of on-demand travel compared with public transport. This confers a price-competitive advantage to scheduled public transport, potentially leading to crush loads of 140 per cent on some peak-hour train services. Accessibility to public transport improves for people on low incomes, those without a drivers' licence, and people residing in areas distant to urban areas. This brings significant social benefits—and further increases public transport patronage. Introduction of a MaaS scheme is advocated to take pressure off overloaded public transport systems, as payment would be on a monthly subscription basis and therefore the cost would not be felt on each individual trip. The scenario entailing rapid adoption of shared fleets of AVs would place significant demand pressure on public transport in a short space of time—that is, prior to 2031. Given the lengthy timelines associated with extending tram and train networks, it is envisaged that buses will assume an increasingly important role.

According to the discussion paper *Automated vehicles: are we ready?* (DTMR 2015) AVs could either complement or replace public transport, perhaps dependent on contextual factors such as land-use density. Under the complementary scenario, the new technology reduces public transport operating costs and attracts riders due to better levels of service (including reliability). New on-demand services take patrons from low-density environments, thereby improving accessibility to the system. Moreover, the paper noted that even with a doubling of road capacity, AVs would not provide a viable alternative to high-capacity metro systems capable of transporting 70,000 passengers
in an hour.

Nevertheless, an alternative scenario was also envisaged as 'people may prefer flexible on-demand AVs providing door-to-door service over scheduled bus services with spatial and temporal constraints' (DTMR 2015: 10). The paper also predicted taxis might be the first type of public transport to be out-competed by AVs.

Clearly there is a lot of opportunity to reverse declines in public transport, especially in areas of high trip density and travel demand due to better capacity, lower cost and enhanced accessibility—although some markets such as taxis and suburban buses may not survive the disruption.

Encouraging telecommuting and online shopping

Automated vehicles: are we ready? (DTMR 2015) discussed the possible impacts of automated online deliveries. It suggested that although this technology will lead to increased home deliveries from online shopping, there will be a substantial net benefit in terms of reduced traffic congestion. This effect arises because a single delivery vehicle substitutes around 30 private cars. However, the paper also warned these gains will not materialise should consumers dispatch their privately owned AV on retail errands.

Evaluation

The reports received scores ranging from slight to low for the criteria 'Ability to operationalise', which suggest that more work is needed to take promising new ideas into practical actions that can be implemented with our present institutions.

The evaluation of the 'Influencing travel behaviour' innovation domain are shown in Table 10, which should be read in conjunction with the shaded cells in Table 8.

The evaluated documents achieved good scores, ranging from moderate to very high, for the criterion 'Potential for innovation'. This is to be expected from the emerging literature which, by definition, is innovation-focussed. All the reports received a very high score for the criteria 'Minimal disruption to PT' and 'Minimal disruption to AT'. However, the ideas have not yet impacted the dominant transport-planning discourse; hence all reports obtained scores of low to very low for the related criteria 'Impact on policy debate to date'. The ideas showed more promise for the criteria 'Potential for disruption of private car ownership and use', ranging from slight to moderate. This mainly reflects the extent to which this model has become embedded in our institutions.

Table 10: Policy document evaluation: Influencing travel behaviour

Criteria / Type of innovation	Lessening car dependency			Addressing declining PT us		Encouraging telecommuting /shopping
Ability to operationalise						
Scalability: from 'niche' market to mobility 'regime'						
Potential for innovation						
Access/inclusion: affordable, safe, legible						
Potential for disruption of private car ownership and use						
Minimal disruption to PT						
Minimal disruption to AT						
Impact on policy debate to date						
Extent of impact to date						
Disruption of private car ownership and use						
Transferability?						

Note: PT = public transport; AT = active transport. *= Very low (1),* *= Low (2),* *= Slight (3),* *= Moderate (4),* *= Very high (5).*
Source: IA (2019), IA (2018b), IV (2018), DTMR (2015).

4.2.3 Innovation domain: Urban structures

High-value local activity centres to lessen commuting

High-value local activity centres to lessen commuting is a normative response discussed by three of the four emerging policy documents.

The *Australian infrastructure audit* (IA 2019: 273) argues that: 'Activity centres and higher-density areas require a mix of infrastructure and policy solutions, such as high-capacity public transport, robust parking policies and prioritisation for pedestrians and cyclists.'

The audit recognised the need for cities to densify and reduce urban sprawl, observing that in Sydney, greenfield development comprises only 20 per cent of new growth: the corresponding figure for Melbourne is 30 per cent, and for Perth 70 per cent. However, the audit acknowledged the pressure placed on legacy infrastructure by new brownfield development, and points out that metropolitan growth increases pressure on transport networks. The paper calls for better integration of land use and transport planning to mitigate problems such as traffic congestion and overcrowding on public transport. Ultimately, a whole-of-government approach is required to ensure alignment of new transport infrastructure provision with new developments in residential, health and education that comprise future sources of travel demand.

Outer urban public transport (IA 2018b) also takes up the theme of the need to integrate transport and land-use planning. In a call for more transit-oriented development, Recommendation 6 of the report states: 'Australian governments should undertake integrated land use and transport planning to examine opportunities for employment and residential densification at key sites adjacent to public transport' (IA 2018b: 72).

The key to unlocking this opportunity is better governance and the report urged governments to 'establish implementation strategies and institutions with the right governance, funding and authority to ensure the planned infrastructure enhancements occur alongside densification' (IA 2018: 72).

Governments are also urged to 'develop corresponding metropolitan and local strategic plans to reflect potential for densification, including adequately assessing the capacity of existing social and economic infrastructure' (IA 201b8: 72) and to 'explore the feasibility of value capture mechanisms' (IA 2018b: 72) for transport projects. The concept of the transit-oriented activity centre is extended to outer urban settings. As such, Recommendation 7 is for governments to 'support the development and growth of suburban and outer urban employment centres to improve job accessibility' (IA 2018b: 77).

Infrastructure Victoria takes a different approach to land-use planning than its federal counterpart. *Advice on automated and zero emissions vehicles* (IV 2018) recommends authorities should have a flexible approach to manage the AV transition, suggesting government jurisdictions should 'create flexibility for property owners and local authorities to adapt to future changes due to automated and zero emissions vehicles' (IV 2018: 13). Their modelling suggests that accessibility in the middle and outer suburbs will be increased by AVs—one consequence of which will be more employment and population dispersal. However, according to IV (2018: 33), 'this is not going to increase sprawl as long as zoning provisions allow for new medium-density development in middle and outer ring suburbs'.

The increased housing demand anticipated for Victorian regional cities and Melbourne's peri-urban areas 'could be accommodated via infill development and small increases in densities, such as through medium-density housing developments' (IV 2018: 33).

Although the variability of urban density and the policy mechanism of land-use planning is raised by all three documents, only the two IA reports explicitly advocated for compact, mixed-use centres, ideally close to high-capacity public transport.

By contrast modest, the IV report saw incremental infill as an appropriate response to manage the growing demand for housing in outlying areas rendered more accessible by AVs. This approach would appear to lessen the role for active transport and conventional scheduled public transport due to less compact and heterogeneous forms of development—although the IV paper does anticipate growth of public transport patronage under all their modelled scenarios. Moreover, the absence of comprehensive and enforceable urban design guidelines risks loss of tree cover due to blanket application of medium-density codes, with the associated 'heat islands' further discouraging active travel modes.

Improving public transport on the urban fringe

The *Australian infrastructure audit* (IA 2019) outlined the challenges facing outer urban public transport, their historic causes and some viable responses. The audit noted public transport accessibility and level of service is low in outer urban areas. As a consequence, public transport has a low travel mode share, particularly for non-work trips and outside peak travel times. This raises social equity concerns, as residents either face the financial burden of lengthy trips by car or experience social exclusion. It identified the historic cause of the problem being the incremental radial extension of rail lines from their urban cores, which resulted in widely spaced train stations and few alternative services in outer urban areas.

The audit argued that an effective short-term response is to encourage public transport transfers with a longer-term focus on building orbital routes. It also identified the importance of other attributes of well-functioning integrated public transport networks, including:

- service hierarchies
- grid structures where orbital and radial routes connect
- high frequency of service (or temporal coordination between connecting services) preventing long wait times during transfer
- interchanges accessible to active travel including bike and e-bike storage
- integrated ticketing.

The objective of improving transit on the urban periphery is central to the report *Outer urban public transport* (IA 2018b). All the issues and opportunities discussed by this report relate to this topic and have already been discussed in this section. To summarise, they included:

- using new technologies (such as AVs) and business models (including ride-hailing and MaaS) to improve public transport accessibility and create on-demand transit in low-density environments
- improving active transport infrastructure in public transport catchments and providing bike storage and bike/e-bike hire services at train stations;
- encouraging land use and transport integration to create mixed-use higher-density transit precincts.

Evaluation

The evaluation of the 'Urban structures' innovation domain is shown in Table 11, which should be read in conjunction with the shaded cells in Table 8.

The measures discussed by the documents concerning the sub-topics 'High-value local activity centres to lessen commuting' and 'Improving public transport on the urban fringe' achieved a moderate to very high score for several criteria including:

- 'Scalability: from "niche" market to mobility "regime"'
- 'Access/inclusion – affordable, safe, legible'
- 'Minimal disruption to PT'
- 'Minimal disruption to AT.'

These scores reflect the ability to build on past efforts, as demonstrated by:

- the high rate of urban infill already achieved by Sydney
- recent extensions of Sydney's high-capacity metros—i.e. scalability
- potential for the design of activity centres and public transport systems to achieve accessibility and equity outcomes
- low potential for any of the discussed measures to 'disrupt' environmentally benign modes of travel—such as walking, cycling and transit.

The measures outlined by the documents to stimulate the development of activity centres capable of reducing commuting demand, and steps to improve outer urban public transport received scores of 'moderate' to 'very high'. These high scores show the broad applicability of the principles informing the proposed interventions for Australia's metropolitan cities, such as:

- achieving a threshold of density and diversity
- managing parking demand in suburban growth nodes
- improving public transport network integration.

The three documents covering the sub-topic of 'High-value activity centres to lessen commuting' receive a lower score of 'slight' for the criterion 'Ability to operationalise'. This recognises the difficulty of overcoming institutional barriers and the absence of any new insights into achieving better implementation short of what has long been suggested—namely transport and land-use planning integration and coordination across government corporate 'silos'.

However, the *Australian infrastructure audit* (IA 2019) achieves a higher score of 'moderate' under this criterion for the sub-topic of 'Improving PT on the fringe'. The score takes into account the practical steps to improve the integration and reach of outer urban public transport suggested for both short-term and long-term time horizons. These include responses such as:

- encouraging transfers between routes
- providing bike lockers at stations (near-term actions)
- providing integrated ticketing
- developing new 'orbital' lines (intermediate to long-term actions).

The majority of these steps can be implemented without too much difficulty by transit providers and transport agencies. However, a 'very high' score cannot be awarded given institutional constraints such as:

- the regimes governing funding allocation
- the existing regulations and standards
- the entrenched habits ingrained in organisational cultures.

These can be expected to provide at least some 'headwinds' to operationalisation.

Calls for a polycentric urban form comprising well-developed 'activity centres' have made significant inroads in the Australian policy environment. The measures outlined by the two IA reports *Outer urban public transport and Australian infrastructure audit* (IA 2018b; 2019) will further strengthen this discourse. These two reports are therefore allocated a moderate score for the criteria 'Impact on policy debate to date'. However, the more laissez-faire approach taken in *Advice on automated and zero emissions vehicles* (IV 2018) has not impacted the policy deliberations. Ironically, the modest, market-directed suburban infill the document espouses is far more characteristic of the urban consolidation being experienced in many metropolitan districts than the fine-grained mixed-use activity centres populating the pages of many Australian strategic planning documents.

The proposals for better outer urban public transport via network integration and emerging forms of on-demand transport espoused by *Outer urban public transport* receives a slight score for the criteria 'Impact on policy debate to date'. This recognises the difficulty of advancing new ideas given the 'accepted wisdom' concerning the so-called 'transfer penalty' and the tradition of extending radial lines to growth areas.

The 'Extent of impact to date' of measures discussed by the documents relating to the sub-topics 'High-value local activity centres to lessen commuting' and 'Improving PT on the urban fringe' has been slight. This score reflects the difficulty of disrupting our 'path dependent' transportation planning and property development systems. The reports obtained a lower score for the criterion 'Extent of disruption of private car ownership and use to date'. All the reports received a low score other than *Advice on automated and zero emissions vehicles* (IV 2018), which obtained a very low score as AV technology has yet to be commercialised in Australian cities and EVs remain a tiny niche of the automobility market.

Table 11: Policy document evaluation: Urban structure

Criteria / Type of innovation	High-value local activity centres to lessen commuting			Improving PT on the urban fringe
Ability to operationalise				
Scalability: from 'niche' market to mobility 'regime'				
Potential for innovation				
Access/inclusion: affordable, safe, legible				
Potential for disruption of private car ownership and use				
Minimal disruption to PT				
Minimal disruption to AT				
Impact on policy debate to date				
Extent of impact to date				
Disruption of private car ownership and use				
Transferability?				

Note: PT = public transport; AT = active transport. *= Very low (1),* *= Low (2),* *= Slight (3),* *= Moderate (4),* *= Very high (5).*
Source: IA (2019), IA (2018b), IV (2018), DTMR (2015).

4.2.4 Innovation domain: Climate change and pricing

Electric vehicles

The *Australian infrastructure audit* (IA 2019) understood the potential synergies between the transport and energy sectors, and barriers to the further uptake of EVs. It suggested that up to 40 per cent of Australia's vehicle fleet may comprise of EVs by 2040, recognising that the batteries in these cars could form a large potential source of energy storage helpful in managing the variable electricity output from solar and wind generation. The report recognised that the lack of scale economies in our thinly populated remote and regional areas creates a market barrier to the provision of fast-charging stations. This creates substantial 'range anxiety' because of the distances traversed by inter-regional trips.

However, the report also observes that a practical solution to this problem—in terms of public sector provision of charging infrastructure—is already being provided by state and federal governments. This includes a 1800-kilometre network of fast-charging infrastructure from Queensland's southern border to Cairns—an initiative funded by the Queensland Government. Another example cited by the report is the project financed by the Commonwealth Government's renewable energy agency ARENA to provide 21 fast-charging stations between Brisbane and Adelaide (via Sydney and Melbourne). These stations will be no more than 200 km apart. The report also acknowledges efforts by some local authorities to provide some slower kerbside charging infrastructure.

Advice on automated and zero emissions vehicles (IV 2018) proposes practical measures to address issues it anticipates will emerge without timely intervention. These include:

- concerns relating to the growth in peak electricity demand
- risk of capacity constraints in local electricity distribution grids
- potential lack of interoperability between charging stations.

The report recommended a review of 'state-based regulatory settings to allow electricity providers to set demand-variable rates' (IV 2018: 15). It suggested 'amending metering and pricing arrangements to allow for separate "vehicle only" electricity tariffs to be offered to zero emissions vehicle owners to shift the electricity demand from these vehicles away from peak times' (2018: 15). In order to mitigate distribution-based capacity constraints, the report recommends that 'regulatory frameworks governing network investment are reviewed to check that these will facilitate investment in the distribution network to support the uptake of zero emissions vehicles' (2018: 15). It suggests the Australian Government be lobbied to facilitate a review arranged by the COAG Energy Council of potential regulatory barriers to electricity distributors facing surging demand from EVs.

The report also recommends the development of 'standards to govern the design and placement of EV charging infrastructure in public areas' and the development of 'principles for smart charging and integrated payment systems in all charging infrastructure in Victoria to ensure interoperability between various charging infrastructure providers' (IV 2018: 14).

Road pricing

The *Australian infrastructure audit* (IA 2019: 300) saw road-user charging as 'the most economically efficient means of charging for our roads'. It pointed out that technical advances such as GPS and vehicle-to-infrastructure connectivity have removed many implementation hurdles to its adoption. Paradoxically, the rate of institutional-level progress in establishing a national regime of road network charging has stalled. This is due to the absence of what it calls 'jurisdictional champions' (IA 2019: 300) and is an issue of growing concern in light of likely reductions in fuel excise revenue because of the electrification of road transport. There is also a possible risk to registration revenue should there be a pronounced shift to a 'sharing economy' model.

The need for road pricing is also identified in *Advice on automated and zero emissions vehicles* (IV 2018). In addition to the revenue-related risks driven by a transition to electric mobility, the report saw congestion-related risks as being a major issue with AVs and, to a lesser extent, EVs (as lower running costs result in a small amount of induced demand). Plausible AV scenarios in the absence of road-user charging include so-called 'empty running' of vehicles, where the car is sent home by its occupant to avoid parking fees, or sent on numerous errands. It identifies a 'trigger' for action being a sudden increase in the number of EVs or AVs.

According to their modelling (IV 2018), the 'empty running' effects are most apparent in the CBD and inner city, as these areas are rich in employment and have parking charges to discourage commuting by private car. Hence workers have an added incentive to send the car back home to avoid the cost of parking. A consequence is growing congestion—an increase of 29 per cent over their 'base case' scenario of no change if all AVs were to be privately owned. Buses would lose travel speed of around 5.5 minutes per kilometre. The report recommends an area-based cordon charge to mitigate the effects of 'empty running' and the unintended effect of the parking levies.

Parking pricing

In addition to recognising the need for inner-city congestion pricing because of the declining utility of parking levies, *Advice on automated and zero emissions vehicles* (IV 2018) recognised that concerns relating to vehicle access will emerge as an issue of growing importance. In this envisaged future, shared or privately owned AVs drop off or collect their occupants or owners from high-demand areas such as railway station precincts or main streets. The report contains the following recommendation respecting the management of kerb spaces:

> Introduce flexible kerb space in high density areas, driven by real-time data to intelligently adjust permitted kerbside uses at different times, including the potential to apply pricing to kerbside use, to ensure that space both meets demand and achieves local transport and land use goals. (IV 2018: 72)

Evaluation

The evaluation of the 'Climate change and pricing' innovation domain can be seen in Table 12, which should be read in conjunction with the shaded cells in Table 8.

The interventions and steps outlined by the evaluated documents for the 'Climate change and pricing' domain of innovation were scalable and showed potential for innovation as seen by the moderate to very high scores allocated to the associated sub-categories: electric vehicles, road pricing, parking pricing. Production of EVs and installation of fast-charging infrastructure is inherently scalable. Measures to introduce road and parking charges are similarly scalable—they can readily apply to a precinct or city as being a nationwide measure. The technology and regulatory environment continue to show potential for innovation, as we are only in the early stages of the mobility transition.

The reports scored moderately well for the 'Access/inclusion' criteria. Electrification promises to reduce the direct financial costs of travel and, when combined with public interest regulations, promise to reduce the indirect, social and ecological costs (or 'negative externalities') by prioritising shared travel and public transport accessibility. These sub-categories can form a complementary 'package' of solutions that guide and build upon technological progress without harmful 'disruption' to sustainable transport modes such as public transport and active travel, as reflected by the favourable scores allocated to this criterion.

Focussing on the Australian context, the extent of impacts from initiatives such as transport-sector electrification and congestion charging are low to very low. The extent of the disruption to the dominant car-ownership and use model is very low for all documents across the associated sub-categories. The limited impact of the initiatives discussed by the documents underscores the amount of work that remains to be done in the Australian context —both in terms of further policy development, action planning and resourcing of measures.

Table 12: Policy document evaluation: Climate change and pricing

Criteria / Type of innovation	Electric vehicles		Road pricing		Parking pricing
Ability to operationalise					
Scalability: from 'niche' market to mobility 'regime'					
Potential for innovation					
Access/inclusion: affordable, safe, legible					
Potential for disruption of private car ownership and use					
Minimal disruption to PT					
Minimal disruption to AT					
Impact on policy debate to date					
Extent of impact to date					
Disruption of private car ownership and use					
Transferability?					

Note: PT = public transport; AT = active transport. *= Very low (1),* *= Low (2),* *= Slight (3),* *= Moderate (4),* *= Very high (5).*
Source: IA (2019), IA (2018b), IV (2018), DTMR (2015).

4.2.5 Innovation domain: Infrastructure procurement

Value capture

The practice of recovering infrastructure costs by 'capturing' a portion of the associated uplift in land value is covered in the two IA policy documents assessed as part of this report.

The *Australian infrastructure audit* (IA 2019) noted there is an opportunity 'to expand existing revenue sources by improving mechanisms such as value capture' (IA 2019: 300). The audit described the process of land-value uplift as 'socialising some of the uplift in prices' (2019: 300), with the state sharing in the windfall gains from property price growth following provision of transport infrastructure investment. In this way projects 'can reduce the funds needed from other taxes and user-pays sources' (2019: 300). This, the report suggested, creates an opportunity 'to improve the financial sustainability of our transport networks' (2019: 300).

Outer urban public transport (IA 2018b) highlighted concerns relating to the low travel-mode share and high operating deficits of Australian public transport systems. It recommended measures such as land use and transport planning integration to create compact, mixed-use developments oriented to public transport, and provision of more integrated networks with new orbital routes complementing existing radial lines. Recommendation 6 of the report (IA 2018: 8) calls on governments to 'explore the feasibility of value capture mechanisms to fund transport infrastructure'. In light of high public transport operating deficits, the report lists numerous steps that could be implemented by governments to improve cost recovery, including 'investigating value capture opportunities, particularly at new transport interchanges' (IA 2018b: 15).

Evaluation

The evaluation of the 'Infrastructure procurement' innovation domain can be seen in Table 13, which should be read in conjunction with the shaded cells in Table 8.

The two IA reports clearly understood the rationale and policy justification for land-value capture as an infrastructure funding model. However, they do not provide any clarity to decision-makers or policy advisers regarding how this high-level principle might be implemented—which accounts for the low score on the associated criterion 'Ability to operationalise'. This funding mechanism has high scalability and considerable potential for innovation. The reports achieved a moderate score for the related criteria 'Scalability: from "niche" market to mobility "regime"' and 'potential for innovation' recognising that while value capture is widely applicable, there are cases where it will play a negligible role, and that the capacity for further innovation will hit practical financial and institutional limits.

The criteria of 'Access/inclusion: affordable, safe, legible' is awarded a slight score, reflecting the ability for alternative funding models such as value capture to ease pressure on funding and reduce reliance on farebox revenue. This, in turn, will make services more affordable—or at least moderate further fare increases.

However, much of the network consists of services with low 'load factors', and thus high operating deficits limit the ability to defer fare increases. Furthermore, there is a risk that relying on user-pays models such as value capture will reduce the affordability of new transit-oriented developments for 'key workers' and first home buyers—thereby ensuring that the most transit-reliant groups reside in the least transit-accessible communities. Although value capture can be justified on social grounds—as explained by the *Australian infrastructure audit* (IA 2019)—this is very much a case of the social outcomes 'devil' lying in the policy 'detail'. The lack of any operational clarity does not aid jurisdictions in crafting policies that maximise the social good while minimising negative social externalities.

Any measure that increases revenue to public transport can play a useful role in reducing car reliance. However, taken in isolation, this measure is unlikely to fundamentally disrupt private car ownership and use, and is thereby awarded a slight score against the related criteria 'Potential for disruption of private car ownership and use'. This is not meant as a criticism—cities that have successfully turned the tide on mass ownership and use of private cars have frequently done so by a package of complementary solutions, with each of them—like value capture—contributing a role in a solution that can become synergistic.

The two AI reports have only recently been released and do little more than provide high-level statements. As such, they have not had a major impact on the policy debate to date and are awarded a slight score on the criteria 'Impact on policy debate to date'. The extent of their impact is necessarily lower, in light of the long timeframes from policy gestation to institutional reform, and then to the delivery of complex infrastructure projects. They are therefore awarded a low score on the related criteria 'Extent of impact to date'. They are yet to demonstrate any ability to disrupt the private car ownership and use approach in Australia, and are therefore awarded the lowest score on the related criteria 'Disruption of private car ownership and use'.

Table 13: Policy document evaluation: Infrastructure procurement

Criteria / Type of innovation	Value capture for funding projects	
Ability to operationalise		
Scalability: from 'niche' market to mobility 'regime'		
Potential for innovation		
Access/inclusion: affordable, safe, legible		
Potential for disruption of private car ownership and use		
Minimal disruption to PT		
Minimal disruption to AT		
Impact on policy debate to date		
Extent of impact to date		
Disruption of private car ownership and use		
Transferability?		

Note: PT = public transport; AT = active transport. = *Very low (1),* = *Low (2),* = *Slight (3),* = *Moderate (4),* = *Very high (5).*
Source: IA (2019), IA (2018b), IV (2018), DTMR (2015).

5. Innovation and Australian urban transport

Section 5 turns to the final research question, which seeks to identify what forward positions should be considered for Australian metropolitan transport programs and policies in response to drivers of major transport system change. We also identify what further research is needed to inform this positioning.

5.1 Directions for Australian urban transport policy

5.1.1 Summary: Current Australian policy approach

Drawing on Section 4, there is a growing appreciation of the 'disruptive' potential of new and emerging technologies and business models, and the need to mitigate climate change impacts by promoting shared transportation and managing travel demand. However, concerns remain over the high share of trips undertaken by privately owned motor vehicles.

All three states are continuing with a land-use and transport planning response begun in the closing years of the twentieth century. The land-use approach essentially entails an inverse of post-war land use policies encompassing a strict regime of land-use segregation, low-density development and minimum car parking requirements.

The new response entails developing compact, mixed-use 'activity centres' and 'activity corridors' oriented to high-capacity public transport and sometimes including maximum parking ratios. All three states are seeking to expand their public transport networks, with an increased focus on orbital lines and new routes serving destinations outside the CBD. There is also a recognition of the importance of supporting active modes of travel via lanes and paths for cyclists and pedestrians.

The development of orbital lines and the recognition of the need for an integrated public transport network have emerged as an optimal policy bundle for the transport sector. Examples of such initiatives include new airport lines in Perth and Melbourne as reported in the *Perth and Peel @ 3.5 million* (DTMR 2018) and *Simple, connected journeys* (DoT 2019). Both cities are also developing middle suburban orbital routes such as Perth's Thornlie–Cockburn link and Melbourne's Suburban Rail Loop.

A number of plans, including Sydney's *Future transport strategy* (TfNSW 2018b) and Melbourne's *Simple, connected journeys* (DoT 2019) outline qualitative innovations regarding public transport line capacity, system reliability and accessibility to people of different ages and abilities. These innovations are underpinned by advances in computer technology—such as line automation—and informed by inclusive design principles. This design ethos applies to the planning of train stations, tram stops and vehicles. These measures are scalable and capable of ready operationalisation, given the scope and clarity of the strategic vision. Together they also form an optimal policy bundle.

Planning 'activity centres' and 'activity corridors' and developing a new methodology to distinguish between the 'movement' and 'place' attributes of streets advances the new land-use planning agenda. An innovative example lending itself to ready operationalisation is provided by *Movement and place in Victoria* (DoT 2019). Their 'Movement and Place Framework' can be applied to both a strategic and a project level by helping decision-makers evaluate their responses to land use and transport planning along road networks, and identify promising

areas for development intensification. Sydney's *Future transport strategy* (TfNSW 2018b) incorporates the same innovation, stating: 'The Movement and Place framework provides a tool to manage the road network. The framework will guide specific corridor and place plans to be developed. A Movement and Place Practitioners Toolkit will be made available to provide guidance to stakeholders involved in planning, designing and operating the road network' (2018: 17).

The theory and practice of identifying 'place streets' or 'activity corridors' is an example of a highly 'transferrable' innovation that can be scaled and operationalised, and which forms another optimal policy bundle capable of at least some 'disruption' to the private car ownership model by improving access to services and public transport. However, the car remains firmly entrenched in the three case study states, suggestive of the challenge of 'disrupting' this business model, and the amount of planning and implementation still required to make a substantive change.

5.1.2 Implementing the new urban agenda

Despite such examples of ideas capable of operationalisation, the ability to properly implement this new urban agenda continues to be impeded by governance and regulatory barriers. These constrain the ability to holistically integrate transport and land-use planning and align new land development with timely provision of infrastructure. Some jurisdictions are further along this transition than others, with Sydney achieving as much as 80 per cent of its new development in existing urban areas. The corresponding figure for Melbourne is 70 per cent, and for Perth 30 per cent.

Further examples of such governance and regulation constraints relate to the lack of road-user charging and patchy implementation of maximum parking ratios. Road-user charging will emerge as a critical issue as we transition to EVs and AVs. EVs will erode fuel excise revenues, and without road-user charging there is likely to be less shared use of AV fleets. For the immediate future, parking caps and levies are an important demand-side response to foster development intensification of 'activity centres', while protecting their amenity. New parking and kerb-space management considerations will emerge in coming years—for example, the advent of AVs threatens to make parking levies counterproductive by encouraging 'empty running'. Innovative new thinking around inner-city road-user charging and demand-responsive kerb access pricing regimes is provided by *Advice on automated and zero emissions vehicles* (IV 2018). However, the ability to operationalise and scale these ideas is challenged by a regime of fragmented urban governance. Further, while the *Australian infrastructure audit* (IA 2019) underscores the potential benefits of road-user charging, it also draws attention to the lack of progress to date despite supportive technical advances.

The failure to recover infrastructure costs through land-value capture is another symptom of this underlying governance problem. None of the three states has a comprehensive approach to this funding mechanism, despite its endorsement by IA at the federal level. Some progress can be anticipated in Melbourne, given the commitment to fund affordable housing via value capture outlined in *Plan Melbourne* (DELWP 2017). However, there is no evidence of more widespread application of this measure in spite of its inherent scalability applicable to a variety of new development projects. In Sydney, the *Future transport strategy* (TfNSW 2018: 141) only commits to continue assessing 'opportunities for value sharing' and to 'identify balanced beneficiary models including value sharing and developer contributions'.

Turning to opportunities from new mobility technologies and business models, we observed the following. While the ideas discussed by the formal government and emerging policy papers show potential to 'disrupt' the private car model and reflect innovation in thinking, the observed impacts remain muted, and there is difficulty in operationalising many of the recommendations. While the lack of substantive impacts to date largely reflects the novelty of these emerging models and technologies, the lack of clarity concerning the transition from a strategic planning phase to an implementation phase is of concern. These issues can be illustrated with reference to specific cases.

E-bikes and e-scooters

E-bikes and e-scooters, together with supportive 'sharing economy' business models, are identified in the *Future transport strategy* (TfNSW 2018) as a means to widen the pedestrian and cycling catchments of suburban railway stations and activity centres. However, the ability to hire an e-bike or to ride safely at higher speeds is lacking. Roads remain clogged with traffic and bike path designs do not take account of the new operating requirements of the faster travelling e-bikes. There is little clarity on measures that can capitalise on these new technologies and business models.

AVs

There is a growing level of understanding in the formal and emerging policies that automated and on-demand public transport have the potential to improve accessibility to transit systems, as well as reduce their operating costs. However, among the three states that were investigated, concrete steps to support this transition appear largely confined to NSW.

Transport for NSW is pursuing an optimal bundle of measures, including several pilot projects and industry and research collaborations. Although some of the support for AV is informed by an economic-development perspective—with a lot of the technology development and implementation left to the market—broader social considerations are also being taken into account. A comprehensive approach to investigate the transport and land-use planning requirements and implications of the AV transition is being planned. Some areas of research—including new requirements for parking management and road-cross section designs—will be capable of future operationalisation via town-planning scheme provisions. The *Connected and automated vehicles plan* (TfNSW 2018a) pledges that it will: 'Work with the Department of Planning and Environment, the NSW Government Architect, Infrastructure NSW and local councils to develop a CAV Built Environment Guide to identify the opportunities and impacts CAVs will have on urban design and planning for the built environment' (2018a: 38). The authors envisage substantive changes including re-purposing for car parks and driveways and improved pedestrian amenity.

Although there is little evidence of a determined strategy to be at the forefront of the mobility transition, Victoria has undertaken innovative research to understand the policy implications of AVs. IV has recently undertaken a comprehensive and long-term scenario planning and modelling exercise to inform future strategic planning during this uncertain, fluid period of mobility transition. The report identifies so-called 'triggers' for action helping to operationalise some of the recommendations as this uncertain future unfolds.

MaaS

More scope for near-term operationalisation is apparent with respect to MaaS. This is achieved via programs that leverage the 'big data' available to government. Victoria's strategic plan *Simple, connected journeys* (DoT 2019) reports a successful transition of MaaS from the planning phase to the implementation phase. Victoria's public transport journey app (Mobile Myki) has helped support development of a third party MaaS app released by Victoria's motoring organisation, RACV. Their Arevo app enables users to plan journeys and book rides on public transport and the Uber ride-hailing platform. The app can also take users to third-party websites to complete booking requests for car-sharing and bike-sharing services.

EVs

Electrification of transport is a relatively easily achievable action to mitigate climate change. However, progress in Australia has been slower than many other comparable countries, largely due to the high purchase price. Promising optimal policy bundles outlined by the *NSW electric and hybrid vehicle plan* (TfNSW 2019) include:

- working with ride-share and car-share fleets to promote electrification at the organisational scale
- revisiting apartment design standards to ensure ability to recharge EVs
- providing subsidies for fast-charging networks in regional areas to address range anxiety.

The Advice on automated and zero emissions vehicles report (IV 2018) recognises that an important part of the coming fuel transition will be provision of common standards for charging and payments to ensure that adequate electricity is available. Measures that are both scalable and compatible with being operationalised are included in the report, including:

- policies to enable peak electricity demand spreading via dynamic pricing
- measures to ensure adequate investment in distribution networks.

5.2 Australia's urban transport technology and policy innovation arrangements

Australian cities are witnessing the rollout of new transport technologies while grappling with the policy and regulatory implications these technologies pose. Such technologies have been discussed in this paper, and include MaaS, ride-hailing, car-sharing and electric micro-mobilities. In addition, urban transport policy-makers are confronting the need to resolve longstanding structural challenges in Australian transport systems via innovative strategic planning and policy approaches. Such structural challenges include:

- sustaining public transport use
- ensuring efficient urban structures
- managing parking
- selecting appropriate infrastructure and financing mechanisms.

This project was intended as a survey of the innovations occurring within Australian cities and the policy responses to them. The project was not expected to undertake a conceptualisation of Australian policy in terms of theories of innovation and sectoral processes and structures that foster and enable innovation.

However, as the research has progressed, and via the conversations within the PRG and the Melbourne and Perth experts' workshops, some key issues in terms of the strategic framing of Australia's urban transport systems, the policy and regulatory frameworks that govern them, and the institutions that oversee these frameworks, have been identified. While these issues emerged later in the project and thus were not able to frame the research discussions, nor were subjected to detailed investigation, they deserve attention here, including in relation to future directions.

Australian transport policy and innovation strategy

Australian transport policy is not currently well positioned to proactively support and enable innovation. Current policy, whether at the national scale or at the metropolitan level, offers very little by way of conceptualisation of innovation processes. In Australia's transport policy system, the implicit perspective on the emergence, adoption and regulation of innovations is underdeveloped when compared to international policy framings. This reductive framing of Australian policy settings operates in two ways.

First, it is generally anticipated by policy-makers that the private sector is the principal agent of transport innovations, particularly through new technologies and new business models that emerge into a competitive sectoral environment, and which succeed or fail on their own merits as 'solutions' to particular problems experienced by consumers or users.

Second, the transport policy system in Australia is not well placed to deliberately foster innovations nor to shape their design or performance to meet social, economic and environmental goals. Some innovations are welcomed by the public sector, such as the Uber flying taxi service—a collaboration between Uber, the Victorian Government and the Australian Civil Aviation Authority. However, in some instances the process of introduction of innovations is often adversarial, as innovations emerge and then policy determines whether their effects

are acceptable, with regulations to shape and manage performance. The case of ride-hailing apps and bike-sharing schemes in Australia exemplify this pattern, with the Melbourne oBike scheme being shut down by the Environmental Planning Authority. Such arrangements do not in themselves represent a policy deficit; there is a competitive market logic to the market introduction and testing of new transport arrangements. However, there are also opportunity costs to wider potential for innovation around societal, economic and environmental goals in transport due to this reactive model. In addition, there are deficits in the way that policy seeks to shape transport systems to social, economic and environmental goals conceived as 'missions' (Kattel and Mazzucato 2018).

Collaborative innovation goals

There are few mechanisms that can enable broad cross-sectoral deliberation or collaboration on the overarching objectives for a transport system—and consequently there are limited opportunities for the development of such shared goals. Private actors pursue their private interests with or without innovative intent, while the framing of policy is often limited to processes involving bureaucratic design with some degree of consultation, or elected representatives determine particular objectives. Large well-resourced lobby groups also influence policy.

In some cases, the existing industry structures may limit the potential for government action to support innovation. Although visions or missions sometimes result from these processes, they are not necessarily shared by all actors within the sector. Hence while transport policy may have formal democratic legitimacy within the structures of representative parliamentary government, the wider forming, framing and embedding of innovation-oriented policy objectives within a more generalised legitimacy may be missed.

There are indications apparent in the review undertaken that the opportunities for innovations with greater social, economic and environmental benefits are being overlooked due to the lack of generalised legitimation, either within the transport sector or the public sphere in general. This includes the:

- lack of focus of the transport sector towards major societal challenges
- lack of elaboration of innovation processes accompanying the few instances where innovation is referenced in policy material.

Further, this deficit may not even be recognised in a policy domain dominated by technical and instrumental perspectives.

Australia's federal institutional structure

Because of Australia's federal institutional structure, each state government pursues its own policy development in urban transport, in the first instance. While Australia's federal arrangements are noted for providing the potential for creativity and innovation at the state level (Twomey et al. 2007)—such as the introduction of new mobility technologies like shared e-scooters—such arrangements also have the potential to generate fragmentation of policy direction in the absence of national coordination.

As the national transport system has become more interconnected across states and territories over recent decades, institutional arrangements for national coordination of transport policy and regulation have evolved, including the:

- Transport and Infrastructure Council (TIC)
- National Transport Commission (NTC).

TIC operates as a forum for Commonwealth, state and territory transport and infrastructure ministers within COAG (now NFRC), and is charged with 'delivering national reforms to improve the efficiency and productivity of Australia's infrastructure and transport systems' (TIC 2019). TIC is supported by a transport and infrastructure senior officials' committee comprising heads of lead state and territory transport agencies. Most of TIC's agenda is focussed on harmonising policy and regulation across the states and territories to support agreed national

directions. This is principally in relation to cross-jurisdictional problems, such as uniform heavy vehicle regulation, or AV rollout. To the extent that innovation is articulated explicitly in TIC's agenda, the focus is principally on removing barriers and capitalising on new technologies by getting ' the right policy and regulatory settings in place' (TIC 2017). Hence there is little consideration of what innovation means in the context of a national transport system, nor how innovation might be fostered and enabled through such a system. There is no overt 'mission' guiding Australian transport policy innovation.

The NTC is a Commonwealth statutory body. It was established in 2003 to contribute to reform in the transport sector by responding to issues raised within TIC. Reform, in the agreement establishing the NTC, is defined as 'model legislation' or 'road transport legislation' or 'other reform'. The objective of reform is to achieve uniform or nationally consistent outcomes (TIC 2003). The activities of the NTC principally involve consideration and deliberation on various transport codes, guidelines, standards, legislation, regulations, rules and charges.

For example, in 2019 the NTC provided advice to TIC on light vehicle standards, regulatory telematics, rail safety and heavy vehicles (NTC 2019). While innovation may be a consideration in the NTC's deliberations, this does not appear to be a prominent concern. The NTC's (2019) automated vehicle reform program—which might be expected to consider the innovative dimensions of such vehicles—mentions the term innovation only once.

Moreover, the NTC appears to operate on a conventional public sector organisational model, rather than reflecting contemporary perspectives of innovative organisations oriented to experimentation and entrepreneurialism (Karo and Kattel 2015). That said, such concerns may not be the responsibility of the NTC itself—Karo and Kattel (2015) argue that not only is organisational configuration important for state-led innovation but also that variety in organisational form is required.

The absence of an innovation dimension to the work of TIC and the NTC should not be considered a deficit in regard to the current management or the professional capability of those organisations. No material reviewed in this research suggests these organisations are not capably performing the function expected of them. However, the issue of innovation potential concerns the overall framing of the national transport policy and regulatory system in relation to innovation, and how institutional design, imperative and variety is derived from that objective (or lack of it).

Wider urban transport innovation

It is worth noting that there are many other organisations involved in aspects of urban transport innovation in Australia. These include such ventures as the iMove Collaborative Research Centre (iMove CRC), which creates and facilitates collaborative research and development solutions to exploit ideas and leading-edge technologies to achieve desired commercial outcomes (iMove CRC 2020).

iMove CRC is part of the Commonwealth CRC program, which funds industry-led collaborations between industry, researchers and end users, with a focus on research application (CRC 2020). While iMove is clearly supporting and enabling technological development, it is not clear from iMove CRC or from the CRC model generally how innovation thinking and practice is explicitly incorporated into the way the organisation is designed and operates. Indeed, the CRC guidelines set by the Commonwealth Government do not appear to reference innovation in any detailed way, and the scheme appears to be more oriented to research and development program than innovation.

As with TIC and the NTC, these observations should not be considered a criticism of iMove CRC as an organisation. Rather, they identify the opportunity for advancing thinking in relation to the national institutional arrangements that can support urban transport innovation in Australian cities. It bears note that a further transport CRC operates in rail manufacturing and, although while this venture expresses concern for innovation, it is focussed on rail systems production rather than urban transport generally.

Beyond the CRC scheme, there are wider ventures in the Australian context aimed at supporting research and development, often with an applied emphasis. For example, the TMR in Queensland supports and coordinates a Transport Academic Partnership (TAP) between three Brisbane universities to support outcomes-focussed and innovative research and development in transport (TMR 2019). While the material available signals that this collaboration aims to foster innovation, it is not clear what the innovation model for the venture is.

A similar venture operates in WA via the Planning and Transport Research Centre (PATREC), involving Perth universities and Western Australian transport agencies. Similar to TAP in Queensland, PATREC seeks to deliver collaborative and applied research and teaching in transport and land-use planning. The collaboration mentions innovation, but this is not a guiding framing of the venture, nor is innovation embedded explicitly in the PATREC agenda (PATREC 2020).

None of this discussion should be considered a criticism of either TAP or PATREC. To the extent that critique is offered, it is of the overall Australian transport system in terms of its capability for innovation at various scales. Beyond iMOVE, TAP and PATREC, there are many further institutes and centres within universities across Australia that undertake research and development in urban transport, as well as various research organisations. Through the work of this project we are not aware of any such entities that have an explicit innovating objective and which operate on the basis of an open, multi-sector model as described in the innovation systems literature (Nesterova et al. 2017).

The evidence from other jurisdictions reported in the earlier literature shows that there are systemic mechanisms that can be adopted to support innovation in transport, and which work by bringing together multiple research, private, public and third-sector stakeholders to deliberate transport opportunities. These mechanisms do not occur of their own accord but are deliberately designed to achieve their purpose, typically by coordinating actors —although sometimes through collaborative consortia. As described earlier, there are various models that might be adopted. An innovation systems approach might be adopted at metropolitan or regional levels by drawing together stakeholders in research, the private sector, policy and government. Living labs might be established that draw together a mix of local stakeholders around particular innovation domains. And innovation bureaucracies could be designed with the purpose of actively pursuing innovations in markets through government intervention, while also pursuing innovation in public policies, institutions and capacities (Karo and Kattel 2015).

5.3 Towards an innovation system for urban transport in Australia

Further research is needed to identify how a fully scoped innovation-oriented urban transport institutional environment can be designed at the local, metropolitan and national scales in Australia. This would necessarily involve a larger scale of research and engagement effort than has been possible within this project. However, an outline of such an arrangement is sketched here.

Institutional inventory

An Australian urban transport innovation framework would first need to undertake an inventory of the current institutional landscape for technical and policy innovation within the transport sector. This would involve mapping private and public capability at local, state and national scales, as well as any international linkages. Within the private sector, this would involve major suppliers of transport services and infrastructure, as well as supply chains. Within the public sphere, this would include the universities and research agencies, together with research funding bodies, government policy and regulatory agencies and service providers. Such effort could be differentiated by mode or sector.

Framing national goals

Next, a visioning effort could be undertaken to frame national goals in urban transport. These would need to reflect major societal challenges, including productivity and environmental imperatives, plus urban demands such as livability and accessibility. While there are various statements within the public sphere about the expectations for the transport sector, including TIC (TIC 2019), there does not appear to be a single national statement establishing the vision for Australian urban transport.

The visioning effort could be accompanied by a performance framework that would establish the expectations for the future operations of the transport system in terms of various economic, social and environmental challenges and goals. For example, this could involve a zero-carbon vision by 2050 (or earlier), or targets for reduction of motor vehicle volumes within dense urban zones. In Victoria, the statutory requirement under the *Transport Integration Act 2010* to prepare an integrated transport plan has largely been ignored by the Victorian Government, but could provide a suitable vehicle for a new innovation-oriented transport policy focussed on a sustainability 'mission'. While a few high-level targets would be simpler, these could have subordinate performance sub-targets. It may be that the Commonwealth Government (or COAG) is required to take a decisive view on innovation performance objectives.

Building cross-sectoral institutional innovation arrangements

The next task would be to identify cross-sectoral institutional arrangements that could respond to the vision and performance challenges. This would include how suitable arrangements might be devised at the level of particular cities, and the mix of institutions present in such contexts that should be involved in the innovation framework. This may need to be devised through an open process of participation and development, including setting performance objectives for that jurisdiction. Such arrangements could include establishment of 'living labs' (Gatta et al. 2017; Nesterova et al. 2017; Quak et al. 2016) or 'innovation hubs' (Mazurek and Stroinski 2020) oriented to comprehensive or specific transport sector problems. Bulkeley et al. (2016) explicitly recognised that living labs are a form of governance that can enable innovation and experimentation. New transport living labs would need to include a diversity of stakeholders across academia, government, the private sector and relevant non-governmental organisations.

Reforming agencies

Should an innovation objective be deemed desirable, then reform would likely be needed to reset the agendas for existing transport agencies at both state and federal levels so that innovation can be embedded within their activity. An explicit shift in agencies such as the NTC could be considered, so they become active facilitators of innovations by fostering multi-sectoral collaborations across the urban transport system. Alternatively, a dedicated separate national urban transport innovation agency could be established, with the specific purpose of enabling and coordinating across the sector and at national and metropolitan scales, including state agencies, firms and universities. At the state level, innovation agendas could be enshrined in urban transport legislation, such as the *Victorian Transport Integration Act 2010*. That legislation, for example, does not include an innovation purpose or objective, except in relation to commercial passenger vehicle services.

This outline does not necessarily require a wholesale restructuring of the Australian urban transport sector. The inclusion of an innovation agenda could be introduced via modest adjustment of various existing transport institutions, policies and regulations. However, importantly, it may require a substantive shift in attitude among those organisations, rather than doing 'business as usual' with an innovation veneer.

In this context, it should be noted that the Australian Academy of Science (O'Donnell et al. 2019) has advocated for the establishment of an innovation perspective on Australian cities in support of sustainability transformations, which has relevance to transport innovation challenges. The academy has proposed a national institutional framework to link urban and regional research, policy and practice communities and recommended that a national network of innovation hubs be established to empower such urban and regional innovation (O'Donnell et al. 2019). While the academy's recommendations are focussed on urban questions generally, there is no reason why this innovation model could not be adopted in the transport sphere. Indeed, a national transport innovation program organised at the urban scale could contribute to the wider innovation hubs envisaged by the academy.

Summary

In summary, there are many directions that could be pursued for Australian cities by urban transport policy-makers. These would require further deliberation as to the optimum design of alternative arrangements. However, simply establishing an innovation framing of Australian urban transport policy that uses contemporary theories of innovation —including innovation systems, cross-sectoral collaboration, sustainability transitions and public sector innovation —would be an advance on the current limited policy approach.

5.4 Questions for further research

Three sets of questions for further research can be identified out of the study relating to the main areas addressed in the research. These include:

1. The relationship of innovation theory to the Australian urban transport context, including prospects for institutional evolution to a more innovation-oriented policy and regulatory framework.
2. Development of knowledge of innovation domains in both their international and Australian contexts.
3. Potential policy directions that could strengthen Australian urban transport innovation potential in terms of technology development and application, as well as institutional, regulatory, policy and financial innovations.

5.4.1 Innovation theory and the Australian context

A first need is to better understand the dynamics of innovation within the Australian transport context. There is an extensive innovation research literature, but most of it is founded in European experience and, to some extent, US experience. Australia barely figures as a location for innovation studies, let alone in transport. Hence there are some fundamental questions about the Australian context that deserve to be investigated further:

- To what extent is innovation a guiding construct in urban transport policy and sector development?
- How is innovation currently organised within the Australian urban transport sector and how does this compare to practice in relevant international jurisdictions?
- What is the innovation potential of Australia's urban transport sector(s), including in relation to major societal challenges such as environmental sustainability?
- What are the current barriers to innovation across the domains, and how might urban transport innovation be better fostered and coordinated within Australia's national and state institutional settings?
- What linkages can be drawn within Australia's major cities between innovation within the urban transport sector and wider urban innovation?
- In the context of the above points, what theories of innovation are the most useful for developing effective frameworks for the innovation domains pertinent to Australian conditions?

Each of these questions deserves further investigation and appraisal by urban and transport scholars.

5.4.2 Understanding innovation domains

This research has revealed an array of domains of innovation in Australian cities. Many of these domains have their own specific research questions. The brief set for this report expects a set of further research questions to be identified for future investigation. For the purposes of this report, we have focussed on higher-level further questions to be considered by future studies. We also recognise that many technological innovations are novel because they have been introduced recently, and sometimes unexpectedly, in Australian cities. However, there are also many wider potential innovations involving longstanding policy objectives—such as integrated transport and land-use planning—that are not novel concepts or technologies, but would be innovative if they were to be implemented here.

We consider further questions about the Australian innovation context deserve to be investigated:

- How is Australia positioned as a site of urban transport innovation, whether technological, institutional or operational?
- How do technological innovations in urban transport emerge within the Australian institutional context?
- How can Australia's transport institutional arrangements support innovations in urban transport policy?

5.4.3 Policies to enable innovation

The uneven engagement between policy and innovation across various domains of innovation in Australia implies a set of further research questions. While some of these issues are captured in the research questions on innovation in Section 5.4.1, there are further policy-specific questions that deserve to be assessed:

- How can Australia create an innovation-oriented urban transport policy sector?
- What changes are needed to enshrine innovation objectives within Australian urban transport policy settings?
- What are appropriate governance arrangements for the fostering of urban transport innovation between and across tiers of Australian Government?
- How can 'innovation bureaucracies' be encouraged to support sustainable mobilities transitions in Australia?
- How could cross-sectoral 'innovation hubs' be established in Australian cities to support technological, institutional and policy innovation in urban transport?
- What mechanisms are needed to build collaboration across sectors to support innovation in urban transport?
- What financial mechanisms are necessary to support innovation in urban transport?
- What policy framings and communicative strategies are required to elicit public and political support for innovations that are known to be controversial?

6. Conclusions

This study has investigated the current state of transport policy and planning in Australian cities to identify emerging innovative practices that are responding to the various challenges of rapid population growth, expanding spatial distribution of population and land uses largely dependent on car-based mobility, and growing travel demand, within the context of fiscal constraint and the climate emergency.

It is clear from the analysis undertaken that Australian urban transport faces many issues in grappling with the uptake of market-driven innovations while establishing suitable innovation frameworks for the introduction of public-sector-led innovations in regulation and policy. While Australia has strong public sector institutions and agencies that are highly competent at business-as-usual management of urban transport services, operations, networks, infrastructure and financing, they are less well oriented to proactive framing of future policy targets and outcomes and the innovation frameworks necessary to achieve these. There appears to be little transformative 'mission competency' in the Australian transport policy sector.

While it was not a principal focus of the study, the brief survey of national transport policy and regulatory institutions demonstrates that although there is recognition of the need for innovation, there is little systematic framing of innovation found in the extensive research and policy literature. This deficit presents an opportunity. Australia has many advantages in stable and competent policy and regulatory institutions, including within urban transport.

However, this stability is also a weakness as it may result in opportunity costs in terms of innovations not considered or pursued due to prevailing institutional framings. Such opportunity costs include:

- continued dependence on fossil-fuelled automobiles for the majority of urban travel
- inefficient urban structures
- wasteful competition between modes for investment to serve the urban transport task.

There are also further opportunities for the development of a more sophisticated research and development sector in urban transport that is linked to both private and public imperatives, and which can generate products and services with potential for export.

However, we recognise that this study has only undertaken what should fairly be viewed as a preliminary survey of innovation issues in urban transport. Accordingly, these conclusions should be viewed as raising discussion and debate and prompting further investigation rather than being firm conclusions. Further research is needed to gauge the institutional appetite for reform that orients Australian urban transport to a more ambitious agenda for innovation. This might include qualitative engagement with key actors in the urban transport sphere to assess interest and preparedness for collaboration on innovation agendas or transformative missions.

There are unlikely to be downsides to an early reorientation of the Australian urban transport sector to a more explicit innovation agenda, even in the absence of a more systematic and comprehensive knowledge base. First, this is partly because the costs of enabling innovation are likely to be modest, and largely revolve around institutional frameworks, operating practices and communicative strategies. Second, international competitors are likely to be moving towards such framings, particularly within major economic structures such as China and the EU.

6.1 Key findings

6.1.1 Institutionalising innovation

Institutions and practices

There is an extensive and rapidly growing literature on theories, institutions and practices that can engender innovation within economies and societies at scales ranging from the local to international. This literature has recorded and explained innovations in various domains, including urban transport.

Many mechanisms have been identified that can support innovation, such as technological innovation systems, through which thick relationships are formed between private and public actors around sectoral challenges or imperatives. Innovation is often also framed from a spatial perspective via regional innovation ecosystems that activate networks of proximity between innovation actors to drive innovation potential. There is also recognition of the value of a systems-oriented and transition-oriented perspective on innovation, so that collective societal challenges can be identified and 'mission-oriented' sustainability transitions activated that can establish pathways of succession from one technological configuration to a more sustainable future version.

The role of the state in urban transport innovation

An important component of the theorisation of innovation is the role of the state. This role has been present in much technological innovation, but has only been recognised relatively recently as being essential to the development of technological innovation systems, and to wider programs of transition towards technological, societal and environmental sustainability.

There is a critical need for further elucidation of theories of state framing and fostering of innovation in Australia, including in relation to urban transport. Such theorisation should be both:

- **conceptual**—in terms of a theoretical understanding of the role of the state in innovation
- **empirical**—in terms of expanding knowledge of the capacities of state actors and agencies to establish institutional, policy and regulatory arrangements that can support urban transport innovation.

Such a theorisation in the Australian context would need to be calibrated to the particular circumstances faced in Australia arising from:

- the geographic factors—such as the relative isolation of the country's major urban areas from other large urban areas
- the peculiar governmental structures and divisions of responsibility in Australia arising from the federal constitution.

There is a need to consider what the relevant federal, national—that is, COAG—and state responsibilities are in relation to innovation domains and the institutional frameworks necessary to advance these.

Policy gaps and opportunities

This study has identified an array of innovation domains where there remain considerable knowledge gaps whether these be in relation to:

- technology development and adoption—such as AVs or EVs
- institutional questions—such as the institutional settings necessary to establish generalised road pricing, implement effective multimodal public transport networks or strengthen activity centre planning in major metropolitan areas.

Each of these domains could benefit from further empirical investigation, as well as policy development attention to consider options and pathways.

Much transport innovation in the international literature is oriented to improving the sustainability of urban transport, whether through:

- reducing fossil-fuel demand
- mitigating climate change due to vehicle emissions
- encouraging greater use of public and active transport or micro-mobilities.

Despite references to sustainability in some policy documentation, there remains a clear gap in terms of the sustainability framing in Australian urban transport. This gap could be addressed through a sustainability transitions perspective that would incorporate a combination of technological innovation and institutional reform around a national vision for sustainability.

However, to initiate this direction would require a national sectoral conversation to be held, which in turn raises questions of leadership within the sector. In the absence of innovative leadership, business as usual is likely to prevail.

6.2 Final remarks

The project has only been able to undertake an initial exploratory engagement with general questions of innovation in Australian urban transport. There is a considerable task ahead of researchers and policy observers to improve understanding of international and local innovations, as well as how the Australian urban transport institutional and policy context can be better organised to identify societally desirable innovations for urban transport systems, and the technological and institutional arrangements that can coordinate effort towards achieving them.

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