Last Mile Connectivity / MaaS Lite Feasibility Study

PBA Transit Planning for Bus Association Victoria

1 October 2021

Executive summary

State of play

Melbourne is a city of stark contrasts. The world's "most liveable city" is, at the same time, across middle and outer Melbourne, an endless, sprawling suburbia that is designed and built around the automobile, with environments 'hostile' to pedestrians and public transport sparse or non-existent. Fringe development sites (particularly in Casey, Wyndham, Whittlesea and Hume) have been established as some of Australia's most transport disadvantaged areas (known as public transport deserts). Outer urban developments rely on bus services that are often implemented years after residents move in, with service levels sub-par compared with inner suburbs. Route coverage may be sparse, service frequency low, and operating span limited, with rail and other trunk bus connectivity poor or non-existent (Melbourne's train network only reaches 8% of its population).

First and last mile access challenges come to the fore across metropolitan Melbourne. In recent years, the emergence of a plethora of new mobility services, technologies, and businesses constitutes an opportunity to meet public transport access/egress demands. Bridging the traditional void between private car and fixed-route public transport is ridehailing, carsharing, microtransit and micromobility, which can offer more personalised services and play a role in addressing public transport deserts. Operating in a commercially deregulated market, these new mobility modes are too often an overlay upon an existing transport system, saturating areas of high service and underserving communities with limited transport alternatives. Opportunities exist to unlock synergies where new mobility modes play a feeder role to high-capacity public transport. The missing ingredient is integration across physical service delivery, information, ticketing, governance and funding.

Such integration ideals are captured by the novel new concept of **mobility as a service (MaaS)**, which has caught the enthusiasm of transport regulators, operators, and customers alike. Best defined as a personalised, one-stop travel management platform digitally unifying trip creation, purchase and delivery, MaaS provides total integration across public, private and shared modes of transport. This report establishes a case for MaaS in Melbourne by building an evidence base for suburban Melbourne's first/last mile connectivity challenges. Alternative models of MaaS are explored, capturing different integration levels and roles for the government. A series of innovations, options and reform roadmaps are provided for a more integrated transport system bringing better connectivity to people and places throughout Melbourne.

Methodology

The findings and innovations devised in this report are based on a first-principles approach which establishes the first/last mile as an issue, confirms this hypothesis, and engages industry in the problem definition and solutions development of alternative MaaS propositions. The three empirical components of the research include:

1. **Accessibility analysis:** A desktop study of access to high-frequency public transport. This supply-side, top-down, deductive analysis maps public transport stop/station catchments and identifies four case study sites (plus a benchmark comparison) for additional in-depth analysis.
2. **Station access surveys:** A study of attitudes and behaviour from public transport users. These station intercept surveys provide a demand-side, bottom-up, inductive perspective on the root causes of reduced bus patronage in two selected case study areas.
3. **Stakeholder interviews:** Engages industry to understand the barriers and facilitators towards better transport integration in Melbourne. An ideation process informs the development of MaaS proof of concept options as well as implementation and reform roadmaps.

The (1) accessibility analysis adapts the Public Transport Accessibility Level (PTAL) as a spatial assessment of high-frequency public transport penetration—and, as a corollary, first/last mile access to this high-frequency network. The multi-criteria method is considered best practice and widely applied in many jurisdictions to map public transport deserts. The accessibility index applied to metropolitan Melbourne (Figure 1) shows vast disparities in public transport access between Melbourne's CBD, inner, middle, and outer suburbs. High levels of accessibility are exhibited along train corridors, tram corridors, and to a lesser extent, SmartBus (trunk) corridors. Five locations were selected as deep-dive case studies for in-depth investigation: Point Cook, Doreen, Rowville, Cranbourne East and Bentleigh East.

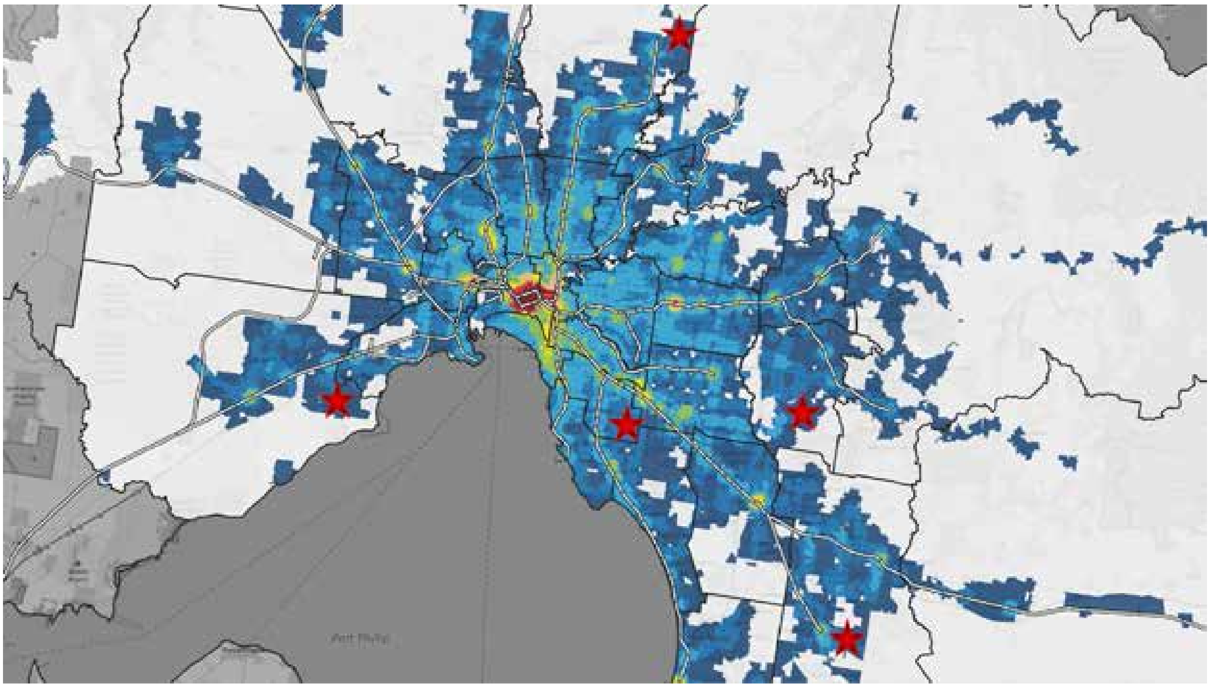

Figure 1: Accessibility analysis of metropolitan Melbourne, showing the five case studies selected for in-depth study

The (2) station access surveys complement the desktop-based, service level accessibility analysis with the aim to understand *why* through a qualitative lens. The stations Williams Landing (capturing the Point Cook case study) and Cranbourne were selected so as to encompass communities of two different socioeconomic profiles and bus network route structures. Computer-assisted personal interviews (n=132) were undertaken, with questions designed around their station access/egress trips, mode choice rationale, and the conditions under which they might consider a mode shift. A focus of understanding attitudes and behaviours enabled a confirmation of the first/last mile access challenge established in the accessibility analysis, coupled with hands-on experiences, an understanding of how personal/demographic factors might affect choice, and a consideration of 'soft' factors which were not captured in the quantitative treatment of service levels.

Finally, the (3) stakeholder interviews provide a supply-side perspective on the reasoning for the current service offering, opportunities for better multimodal connectivity and helping to inform roadmap generation for implementing a MaaS proof of concept. Key informant interviews (n=26 organisations) were undertaken with government, public transport operators, transportation network companies, technology providers, academics, consultancies and trade associations from May to July 2021. Insights were garnered around network planning, scheduling, train/bus connectivity, data sharing, multimodal partnerships, open government, and policy/funding reforms.

Scope of work

This report is structured around a scope of work that links MaaS to the first-principles requirements of solving the first/last mile problem and enhancing transport connectivity. The three empirical components of the research link to different scope items and culminate in the developed innovations, options and roadmaps. Table 1 presents a summary of each scope item and project outcomes, as well as reference chapters/sections for each component.

Table 1: Scope of the report and project outcomes, showing key reference chapters/sections

Project scope items	Project outcomes	Relevant chapter/sections
Investigate and identify the probable root causes of reduced bus patronage in a sample of areas where there are few bus stops, routes or where service frequency is low	Identified areas of low public transport service levels	Sections 4.1-4.2
	Determined barriers to public transport use amongst last-mile bus and non-bus users	Sections 4.3-4.4
	Diagnosed route and network gaps in select case studies	Chapter 5
Provide locations/interchanges that could benefit from the integration	Identified areas of Melbourne with poorer first/last mile connectivity	Section 4.2
	Recommended points of interchange and integration opportunities amongst case studies	Chapter 5
Determine potential services and 3rd party providers	Provided case study-specific recommendations for service reforms and new service provision	Chapter 5
	Identified TNC and technology solutions providers	Section 6.3
	Investigated conditions under which service providers may be willing to participate in a MaaS scheme	Sections 6.4-6.5
Provide recommendations on feasibility and next steps	Developed MaaS implementation options	Section 7.1
	Detailed thematic recommendations to realise each option component	Chapter 8
	Developed reform roadmap for each MaaS option	Sections 7.2-7.5
Provide indicative pricing, timing and project plans for implementing a solution	Provided indicative pricing and complexity for each MaaS option	Section 7.1
	Developed timelines and project plans as part of roadmap generation	Chapter 8
Engage key industry participants in collaborating to design next steps	Collated barriers and facilitators to industry collaboration	Sections 6.3-6.6
	Identified next steps, framed within project recommendations	Chapter 8
Produce a Positioning Paper for BusVic to secure next-stage funding (from either private or public sources, or a mix of both)	Compilation of research motivation, design, outcomes and recommendations	Entire report

Key findings

The combined empirical work component revealed many insights and opportunities for addressing first/last mile connectivity and implementing MaaS. Key findings include:

- The first/last mile remains a pervasive problem in Melbourne, with lower frequent transport network accessibility linked to distance from the CBD and distance from railway lines.
- MaaS is a necessary but not sufficient condition for addressing first/last mile challenges. This is due to a lack of physical services with which to integrate, especially in the middle and outer suburbs. The public transport network is suboptimal, and new mobility modes are heavily geared towards serving the CBD and inner suburbs.
- Network reform and more equitable TNC deployment can provide a more immediate fix to transport accessibility challenges.
- MaaS deployment is not limited by technology but strategy, regulation, data sharing and trust/collaboration.
- The government has yet to establish a role for itself in the MaaS ecosystem, specifically identifying whether it sees itself as a data provider or a customer interface. Evidence shows that a government broker model may face more hurdles than a private (third-party) MaaS integrator.
- Frameworks for data sharing, data standards and establishing a data custodian are lacking. Data sharing is ad hoc and project-based, with the provision of public transport application programming interfaces (APIs) to third parties inconsistent.
- Contractual reform and better incentivisation are key for a market solution to multimodal integration. Strong governance (including subsidies) and pricing signals/discounts can nudge service supply and promote sustainable travel behaviour.

MaaS implementation options and innovations

The primary lesson in this project is that technology exists to solve problems and that many problems have non-technological solutions, which are often neglected amidst the hype and excitement of new innovations. Technology is a necessary but not sufficient condition for multimodal connectivity. Addressing first/last mile challenges at the downstream (e.g., by subsidising ridehailing services) is fundamentally flawed and likely to “throw good money after bad”. MaaS must have public transport as its backbone, and by taking an upstream, data-driven and values-based approach to fundamentally reform the fixed-route network structure, first/last-mile connectivity challenges may be minimised as much as possible. This appraisal process may involve a rethink of our traditionally preconceived notion of public transport and incorporate novel solutions and funding models from the outset (rather than implementing solutions “in search of a problem”). A variety of case study examples illustrate both poor and good practices in this report.

This project has sought to take a holistic, systematic view to reforming transport networks/systems and improving connectivity in Melbourne. It is widely established that a journey is only as good as its weakest link, showing the crucial role of the first and last mile. Building on a framework in terms of a hierarchy of MaaS integration layers, various MaaS reform options have been developed, presented in Table 2. These options range from actions that directly address first/last mile connectivity to a series of MaaS Lite and Full MaaS alternatives (led by the government or third parties), as well as how MaaS may be facilitated via a full market resolution. Each reform option is accompanied by a series of roadmaps with a set of innovations for each priority and implementation phase. More details are presented in Chapter 7.

Table 2: Excerpt of first/last mile and MaaS integration options

Implementation models	**Model A** **Enhanced connectivity**	**Model B** **PTV MaaS Lite**	**Model C** **Third-party MaaS Lite**	**Model D** **PTV Full MaaS**	**Model E** **Third-party Full MaaS**	**Model F** **Total mobility MaaS**
Objective	To address first/last mile challenges by facilitating additional physical services	To establish the PTV app as an extended journey planner	To facilitate a third-party app as an extended journey planner	To establish the PTV app as a one-stop travel management platform	To facilitate a third-party app as a one-stop travel management platform	To build a mode-agnostic MaaS ecosystem where the private sector acts as a total mobility provider
Equivalent integration level (Sochor et al., 2018)	0	2	2	3	3	4
Implementation difficulty	Medium	Medium	Low	High	Medium	Extreme
First/last mile benefit	High	Low	Low	Medium	Medium	High
Role of public/private sector	Full government resolution	Government-led	Market-led	Government-defined	Market-defined	Full market resolution

A comprehensive innovation plan has then been developed that brings together the roadmap actions into nine themed innovations, each consisting of a series of steps further outlined in Chapter 8. These nine innovations are additionally grouped into three categories, targeting physical, digital and governance/procurement:

Physical service innovations

1. **Establish a systematic and embedded public transport network review process**
    a) Commence a comprehensive analysis of public transport accessibility
    b) Identify external catalysts for network reform
    c) Establish a multicriteria ranking to prioritise reform implementation
    d) Work in partnership with transport operators and community stakeholders to deliver a network reform implementation plan
2. **Align public transport service levels with the established service hierarchy tiers**
    a) Define frequency and span requirements at each hierarchy tier level
    b) Allocate routes and cross-check service levels in line with stated policies
    c) Ensure service level definitions are applied consistently across different communities
    d) Ensure greater rigour in the application of service specifications and coordination requirements
    e) Make publicly available datasets showing how each community meets service level requirements

3. **Lead greenfield services with DRT; mature with fixed route**
    a) Assign a standby DRT technology provider for each growth centre
    b) Develop a database of underutilised community vehicle assets and service capabilities
    c) Implement DRT services as new residents move in (within weeks)
    d) Ensure active monitoring of service performance and travel behaviour
    e) Mature services with a fixed route bus offering (within years) and scale assets to new growth areas
4. **Scale new mobility modes, whilst maintaining equity**
    a) Establish an easy approach avenue for private sector operators and technology providers to engage with the government
    b) Develop a template to design, implement and evaluate trial services
    c) Encourage new mobility offerings on the metropolitan fringe
    d) Review and channel developer contributions
    e) Consider the role of public subsidises in supporting equity in the deployment of new mobility modes

Digital infrastructure innovations

5. **Develop a trust architecture and data sharing repository to facilitate TNC integration**
    a) Review the regulations governing each new mobility mode and their right to operate
    b) Establish a comprehensive data-sharing framework for the TNC sector
    c) Appoint a data custodian as an aggregator and intermediary
    d) Implement new regulatory requirements, ensuring the consistency of application across each new mobility mode
6. **Determine the government's role in the MaaS broker/aggregator ecosystem**
    a) Market test which operators are willing to participate in a government-led MaaS ecosystem
    b) Build deep link and native integration capabilities in the PTV application
    c) Establish Myki as a multimodal digital wallet
7. **Support the establishment of third-party MaaS ecosystems**
    a) Establish a catalogue of government-held data feeds, service level agreements and fees
    b) Provide open APIs to third party operators and integrators as government policy
    c) Enable the third-party resale of Myki tickets
    d) Enable mobile ticketing on public transport

Governance/procurement innovations

8. **Review contractual regimes and funding frameworks**
    a) Review the *Transport Integration Act 2010* with an explicit view to incorporate new mobility modes
    b) Provide greater patronage incentive amongst existing mode-specific contracts
    c) Explore user- and supply-side funding support to nudge sustainable travel behaviour
    d) Encourage the development of multiservice MaaS propositions

9. Pilot mode-agnostic mobility contracts

a) Develop a unit accessibility measure as the underlying key performance indicator
b) Set a baseline requirement for minimum service levels and the parameters of operation
c) Design a real-time framework to monitor experienced service levels
d) Engage the market to design a procurement model to pilot an accessibility-based multimodal service contract in a defined geographic area
e) Evaluate service performance and value-for-money on a total mobility (mode shift) basis

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Notes

- "New mobility modes", "shared modes", "TNC modes", and "TNC services" are used interchangeably to describe, as a collective, transport services such as ridesharing, carsharing, microtransit and micromobility, which fill the void between public transport and the private car. Figure 5 provides more details of this schema.
- The definition of mobility as a service (MaaS) is used liberally to apply to a broad spectrum of integrated mobility offerings. The terms "MaaS Lite" and "Full MaaS" are used to better differentiate between low-level and deep integration between modes.
- The MaaS "broker", "aggregator", "integrator", and "provider" are used interchangeably to describe the new business entity that brings transport service providers together and thus becomes the customer interface channel to end-users.
- The "last mile" is used in the main to refer to the first and last mile collectively. "Access" and "egress" are used when describing specific directions of travel.
- The "Department" is used to refer to Victoria's Department of Transport. Distinctions with "Public Transport Victoria" and "Transport for Victoria" are not made.

1. Background

1.1. Why study the first/last mile

Transportation is a fundamental component of the human condition. Access to employment, education, shopping and recreation stimulates economic activity and brings *freedom* to people's livelihoods. For too long, mobility in Australia has been predicated on ubiquitous private vehicle ownership. The follies associated with automobiles such as fossil fuel dependence, air pollution, crippling congestion and urban sprawl are becoming increasingly exacerbated. The social costs of motorised transport are far exceeding the private benefits that they bring.

Public transport has re-emerged as an essential part of the urban modal mix. Prior to COVID-19, public transport usage in Australian capital cities reached record levels (though still low by international standards) and was coupled with significant investments in new infrastructure and (primarily rail-based) projects from the government. Moving people en mass is the *only* scalable solution to the transportation problem in dense urban environments, whilst bringing additional health and social inclusion benefits, as well as supporting agglomeration economies (Daniels and Mulley, 2011). Public transport, by its very design, is able to meet urban mobility challenges not possible under any other mode.

The geometry of public transport

Public transport is efficient because it brings multiple people together onto a single vehicle, thereby reaping economies of scale. Aggregating people with a coincidence of trip times and similar travel origins/destinations generate efficiencies, including the sharing of labour costs, use of the vehicle as an expensive asset, whilst also minimising the unit road space required for each person-trip (thereby significantly increasing throughput on a given corridor). However, the geometry of public transport, which brings these aggregation benefits, also require people to congregate at fixed public transport stops and stations. The mantra "every public transport user is also a pedestrian" encapsulates the walk which is often required for using public transport. This trip component is known as the **first or last mile**—the difference depends on whether this is at the trip start (access) or trip end (egress). The first and last mile may be considered at various scales (e.g., a feeder bus service or drive to a train station in the neighbouring suburb) and can itself be met by active modes, other public transport modes, a private car, or even a plethora of new mobility options.

Public transport network reform

Buses are the workhorse of any city through the sheer spatial coverage of a metropolitan area, including Melbourne, although their service performance and productivity tend to lag behind trains and trams. Ongoing research on growing urban bus markets shows the importance of the 'invisible' service factors to attracting patronage, such as frequency, directness and span (Currie and Wallis, 2008). In past decades, there has been a trend towards consolidating services onto major corridors, accompanied by a higher level of service through increased frequency and speed (Nielsen et al., 2005b, Walker, 2008). Initiatives like bus rapid transit and branded bus services (Hensher et al., 2020) can further concentrate resources and exacerbate the first/last mile challenge.

These same trends manifest themselves in Melbourne. Differences in service design philosophy are particularly profound when comparing bus networks between inner and outer suburbs, with the coverage/frequency trade-off setting also heavily dependent on the era in which network planning decisions were made. Land use and road network layouts can also serve as a barrier or facilitator to optimising network outcomes (Cervero and Kockelman, 1997, Ewing and Cervero, 2010).

Access to high-frequency public transport

Efficient trunk public transport brings first and last-mile challenges and is predicated on providing multimodal connectivity and encouraging transfers. Transfers such as the reliance on a feeder bus already bring inconvenience and travel time, reliability and cognitive penalties to the customer. Experiences from natural experiments show that a patronage loss of 30% can be experienced when a one-seat ride is withdrawn and replaced by a transfer (Wong, 2014). Transfers are particularly problematic where feeder services are infrequent and insufficient.

In Melbourne, a significant focus has been on rail station access, which provides the primary source of high-frequency trunk public transport for the middle and outer suburbs. The provision of commuter parking has often been prioritised (and not without controversy) at the expense of improving local bus networks. More personalised, door-to-door service offerings such as demand-responsive transport (also known as on-demand) have also been proposed and trialled at several sites. Flexible transport services can often be challenging to scale and meet cost-effectiveness and productivity targets (Currie and Fournier, 2019). Recently, there has been a focus on a new wave of technological solutions which can help meet this first/last mile transport task, as well as improve the multimodal connectivity experience.

1.2. The changing mobility landscape

Every other week, we hear new and exciting mobility propositions being announced. Aided by the rise of new technologies like real-time information systems and the near-universal penetration of smartphones, transportation network companies (TNCs) have carved out a new category of transport options that fill the void between private car and public transport previously occupied only by taxis. The growth of this segment is embodied by massive venture capital raisings, the establishment of a plethora of new start-ups, hostile takeovers, and huge investments by some of the world’s largest technology, automotive and financial enterprises. Media personalities, technology visionaries and other proponents jump on the bandwagon, promising how these services can revolutionise and herald a new era of transportation for all.

New mobility services and technologies

One of the significant opportunities is associated with the vast array of digitally-enabled new mobility modes like ridehailing, carsharing, microtransit and micromobility, which have entered the fray under a variety of guises and different operating models (Shaheen and Chan, 2016). Ridehailing [1] is providing a new point-to-point transportation option similar to taxis but in a peer-to-peer format, with the ‘gig’ economy model democratising service delivery and availability. Carsharing enables access to the convenience of the motor vehicle without the costs and hassles associated with long-term ownership. Microtransit is enabled by sophisticated dynamic routing, which can better pool individual trips to unlock a service model that sits in the hybrid space between fixed-route and point-to-point transport. Finally, micromobility is providing a new short distance travel option via e-bikes and e-scooters. Figure 2 shows this variety of new mobility options which are now available to the masses, including in Melbourne.

[1] Also known as ridesourcing or (erroneously) as ridesharing

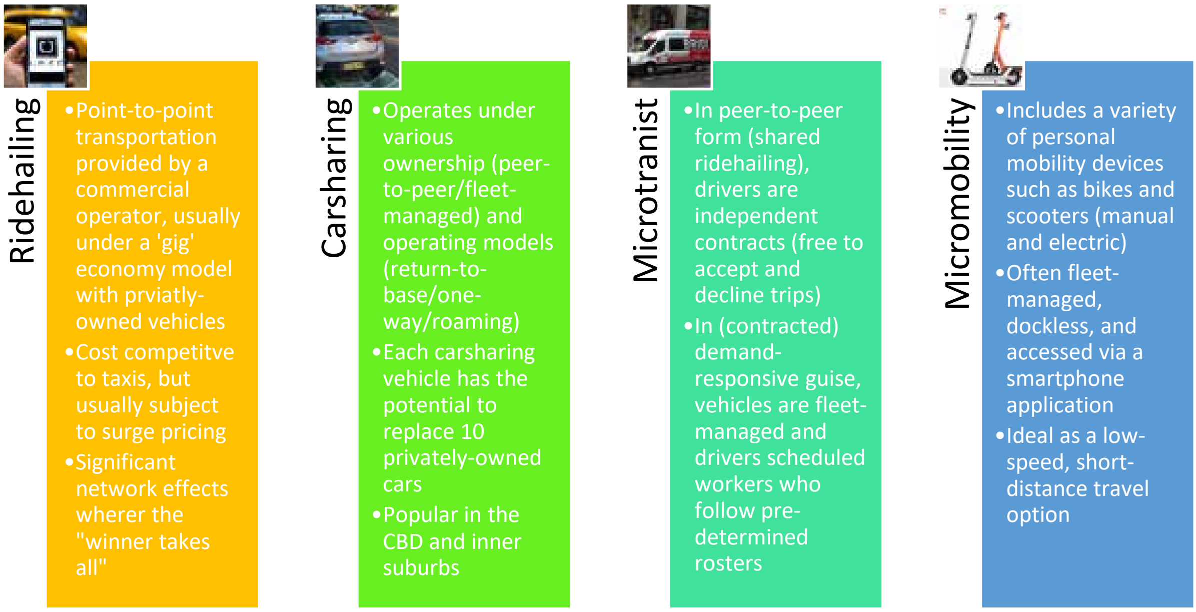

Figure 2: New mobility modes which have been introduced over the past decade

Interface with public transport

Unlike public transport, which is designed and funded by the government and operated under contract by the private sector as almost extended public servants, new mobility modes operate commercially in an economically deregulated market. Services are provided at a higher cost to end-users, but usually with a zero-cost outlay to the government (although there may still be regulatory/administrative costs, as well as social costs and externalities that need to be managed). There exists little control over service planning, including how these modes might compete with public transport (especially when being internally subsidised by shareholders). A range of studies (detailed in Appendix A1) illustrates how the patronage impacts of these commercial services are highly heterogeneous and vary depending on geography and demographics.

There exists immense theoretical potential for these commercial services to boost public transport use by facilitating first/last mile connections to bus and rail stations (Shaheen and Chan, 2016). Public transport is ideal for meeting large travel flow demands, such as radial journey-to-work trips from the suburbs, concentrating in the urban core (CBD). However, public transport struggles in transporting people from scattered locations onto these corridors, as well as serving journey purposes that require more personalised space (such as shopping and attending sporting/recreational activities). The idea of integrating public transport with TNC-provided modes to provide a service that is on par with or exceeding that of private vehicle ownership is often known as mobility as a service (MaaS).

Mobility as a service (MaaS)

The ideals and rationale behind MaaS may be multifaceted, but central amongst these is the desire to enhance multimodal integration. Veeneman (2019: 39) notes that "integration should put all modes in their strength and provide efficient integration between the different modes". Wong et al. (2020) explain how MaaS may be operationalised by bringing together public and shared modes spatially (via a hub-and-spoke model) and temporally (as a peak top-up). This is supported by a one-stop-shop digital platform provided by a MaaS broker/aggregator, which brings together constituent transport operators like public transport operators and TNCs (Wong and Hensher, 2021). Collaboration between these actors is critical, and the institutional regime and contractual framework must be conducive so as to incentivise the provision of multimodal MaaS offerings.

In recent years, a number of MaaS propositions have come to fruition around the world, though the extent of integrating physical services, information, booking, payments and governance vary considerably. MaaS integration efforts have also come online in Melbourne (e.g., Arevo, Placie), though the primary focus on enhanced journey planning capabilities (and to a limited extent, payments) means that these products may be more accurately coined **MaaS Lite**. Full-scale MaaS integration consistent with founding objectives remains in its infancy around the world.

An unfortunate reality is that many efforts to introduce MaaS can be driven by a desire to pursue innovation as an end in itself, far removed from objectives that are contrived or ill-defined (Lyons, 2016). In many cases, MaaS can be a "solution in search of a problem"—and powered by vested business or commercial interests. At its core, MaaS, when guided by an appropriate governance framework and design parameters, can be a journey towards greater sustainability. By helping meet first/last mile public transport connectivity challenges and thereby expand the reach of fixed-route public transport, MaaS can help to reduce private vehicle usage and ownership.

Reconceptualising public transport

One of the recurring themes associated with new mobilities is the blurring of previously distinct concepts. New mobility modes blur previously distinct public and private modes, as technology facilitates new ways of providing transportation. Microtransit propositions are blurring fixed route and personalised modal offerings, while concepts like MaaS are blurring the distinction between contracted and commercial transport services.

Public transport has traditionally been associated with mass transportation options such as buses, trains, trams and ferries. The geometry of public transport in aggregating trips give rise to their productivity and efficiency. However, new mobility modes also bring about efficiency through the use of vehicle assets that are shared between users and do not necessitate the use of a personally-owned vehicle asset (hence the term "as a service"). Ridehailing, carsharing, microtransit and micromobility can also be considered "public" by virtue of not being "private". This transforms the definition of public transport from one associated with large vehicles running fixed routes and *democratises it to encapsulate all non-privately-owned modes*.

This distinction (or reconceptualisation) is particularly relevant in the world of MaaS as governments determine how best to enhance mobility in a digital era and citizens reconsider traditional notions of what it means to step beyond the private car.

1.3. Project objectives

This report seeks to provide a clear evidence base to present a case for better multimodal connectivity through MaaS. The introduction has put forth a number of hypotheses and conjectures. Such notions include that:

- The first/last mile is a geometric reality of public transport networks
- The first/last mile problem is a constraint to public transport use
- The extent of the first/last mile challenge can vary considerably across geographies
- New mobility modes can help fill the first/last mile gap
- A multimodal MaaS platform can provide an enhanced solution that brings together the best of public transport and new mobility modes

This project draws on the best of global research and practice and applies these learnings with an empirical investigation of first/last mile challenges in metropolitan Melbourne. In the field of complex systems attempting to integrate disparate disciplines and approaches, a reductionist methodology can help break down the complex research task into constituent components. The combination of deductive and inductive research methods is hence used to provide a grounded, local perspective and a case study-driven approach to examining the research problem.

The findings and innovations devised in this report are based on a first-principles approach which establishes the first/last mile as an issue, confirms this hypothesis, and engages industry in the problem definition and solutions development of alternative MaaS propositions. The three empirical components of the research include:

1. **Accessibility analysis:** A desktop study of access to high-frequency public transport. This supply-side, top-down, deductive analysis maps public transport stop/station catchments and identifies four case study sites (plus a benchmark comparison) for additional in-depth analysis.
2. **Station access surveys:** A study of attitudes and behaviour from public transport users. These station intercept surveys provide a demand-side, bottom-up, inductive perspective on the root causes of reduced bus patronage in two selected case study areas.
3. **Stakeholder interviews:** Engages industry to understand the barriers and facilitators towards better transport integration in Melbourne. An ideation process informs the development of MaaS proof of concept options as well as implementation and reform roadmaps.

The project adopted an agile sprint project management methodology (Figure 3). These six sprint components together encompass the three empirical work streams introduced above. Full tasks within each sprint are elaborated in Appendix A2.

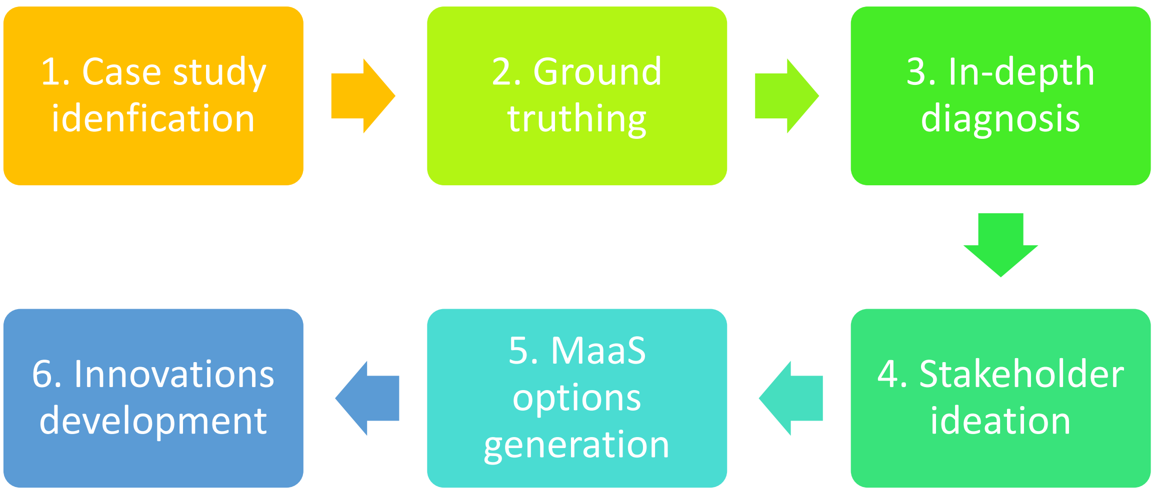

Figure 3: Six sprints (components) of the project plan

The remainder of this report is structured as follows:

- **Chapter 2:** Presents mobility as a service (MaaS) as a journey towards greater integration, summarising recent research, pilots/trials and ongoing challenges.
- **Chapter 3:** Overviews the Melbourne policy context, including service reform history and multimodal integration efforts to date.
- **Chapter 4 (the why):** Present a first-principles approach to analysing access, attitudes and behaviour, presenting findings and identifying what a MaaS proposition aims to solve.
- **Chapter 5 (the where):** Diagnoses the existing network structure in the identified case study areas, identifying critical first/last mile constraints, and recommending complementary services and integration locations.
- **Chapter 6 (the who):** Identifies relevant stakeholders, barriers/facilitators to collaboration and discusses major implementation challenges.
- **Chapter 7 (the what):** Presents a series of MaaS proof of concept options and associated reform roadmaps.
- **Chapter 8 (the how):** Offers thematic innovations for implementing MaaS, linked to each MaaS option and roadmap.

2. Mobility as a service

2.1. What is mobility as a service

Just five short years ago, the term "mobility as a service" was very much unheard of beyond a few select entrepreneurs in Finland. In the years since, it has entered the transport and technology lexicon and become mainstream, as the concept has caught the interest of transport operators, regulators, academics and other industry stakeholders alike across both developed and developing economies.

Overarching vision for MaaS

Today's widespread adoption of the "mobility as a service" terminology may be attributed to a group of Finnish entrepreneurs, most notable of which being Sampo Hietanen, widely proclaimed as the "father of mobility as a service". The core component of MaaS is the term "as a service", which relates to mobility no longer being predicated on ownership and the use of a private car, but rather access to a plethora of mobility modes. Mulley (2017) describes MaaS as the shift from owned physical assets such as a car to the service nature of mobility, consistent with the 'servitisation' of the economy. The MaaS platform is an optimisation engine that enables this vision by combining modes and ensuring a superior customer experience.

In short, MaaS may be defined as a *"multimodal, one-stop travel management platform digitally unifying trip creation, purchase and delivery"* (Wong et al., 2020). Mulley (2017) describes how MaaS is a technological evolution of the decades-old idea of mobility management. Mobility management has at its core the idea of matching the preferences of end-users with service suppliers via a clearinghouse mechanism for information and financial transactions. It is important to note that the genesis of MaaS and its fundamental ideals in providing a wholescale integration of transport modes has been an ongoing, decades-old journey. What is different now is the new appetite for innovation and possibilities facilitated by the emergence and ubiquity of new technologies (especially smartphones).

Defining attributes of MaaS

Many scholars have approached the definitional issue by identifying the defining attributes of MaaS. As an example, Kamargianni et al. (2016) point to three main attributes of a MaaS system: (i) ticket and payment integration to allow for a seamless choice process of combined services to users; (ii) mobility packages that should ideally be long-term and include a wide range of alternatives; and (iii) real-time information and communication technologies integration. Liimatainen and Mladenović (2018) assert that all definitions share three basic ideas: (i) the integration of transport services; (ii) the focus on individual travel needs; and (iii) interaction via a single digital interface.

Integration requirements for MaaS

A variation of this service-based typology (and the approach adopted in this report) is provided in Sochor et al. (2018), which recognises four levels of MaaS integration that are information, payments, mobility packages and government policy. Figure 4 displays this hierarchy and explains what each level entails. Many industry observers confound Level 1 (a better journey planner) as MaaS. Level 2 describes a pay-as-you-go (PAYG) model, while Level 3 includes subscription packages bundled in time-limited periods. The potential for MaaS in linking with travel demand management and thus optimising the transport network has been proposed (Matyas and Kamargianni, 2018). This integration of societal goals constitutes Level 4 MaaS and requires public authorities to act in providing the incentives for citizens to behave sustainably as well as providing rules for the use of infrastructure.

Although Sochor et al. (2018) argue that no one level may be considered better than another because this depends on what the user needs, greater opportunities exist for meeting sustainability goals for cities with greater integration. Technically, MaaS refers to Level 3 and above. However, the need for Level 4 integration has motivated much research—specifically in understanding the design of a governance overlay to ensure that MaaS development is consistent with societal objectives.

Figure 4: Four levels of MaaS integration (Sochor et al., 2018: 10)

Common misconceptions of MaaS

MaaS is often confounded with concepts like ridehailing and on-demand transport, which are just some examples of new mobility services that have garnered significant attention, but (importantly) are not MaaS, describing only application-enabled TNC services. In Australia, the growing interest in government-sponsored demand-responsive services has seen many private operators offer up a microtransit service under the name of MaaS due to a lack of understanding of the concept and desire to join the latest 'craze' or 'bandwagon'. Ridehailing and microtransit all constitute mobility services which could form a constituent component of the mobility *as a service* multimodal proposition. Too often, there is also confusion in the role technology plays in MaaS—examples include describing the linking of new modes or expanding the capabilities of an existing journey planning application as MaaS. Describing what is not MaaS as MaaS risks degrading the entire concept in a way feared to be already happening. The introduction of the term MaaS Lite can help clarify intent and is used in this report to distinguish between extended journey planners and full-scale MaaS.

2.2. Rationale for mobility as a service

Whilst the preceding section provided some definitional aspects of MaaS and, in particular, how it may be accurately described as a 'journey' towards greater integration, this must be framed within the context of integration benefits (and risks) to society and mobility as a whole. This is particularly relevant in the context of the geometry of cities and inherent efficiencies of different modes, as captured by measures of productivity across the quintessential dimensions of time and space.

The modal efficiency framework

This digital disruption and emergence of new mobility options are readily demonstrated by the modal efficiency framework (Wong et al., 2020), which situates all modes along spatial and temporal efficiency dimensions. On the one hand are public modes which are spatially efficient, carrying many people per unit road space, and temporally efficient, by providing revenue service around the clock. On the other hand, private vehicles are spatially inefficient (carrying 1.2 people per vehicle) and temporally inefficient since, under the private ownership model, vehicles are idle (parked) at least 95% of the time. There is a direct correlation between vehicle occupancy and whether vehicles are privately owned, or fleet managed. This large void between total flexibility under the private car and fixed-route/stop mass transit options has traditionally only been filled by taxis but are now accompanied by the advent of new mobility modes such as ridehailing, carsharing, microtransit and micromobility. These modes are generally (but not always) temporally efficient but not spatially efficient.

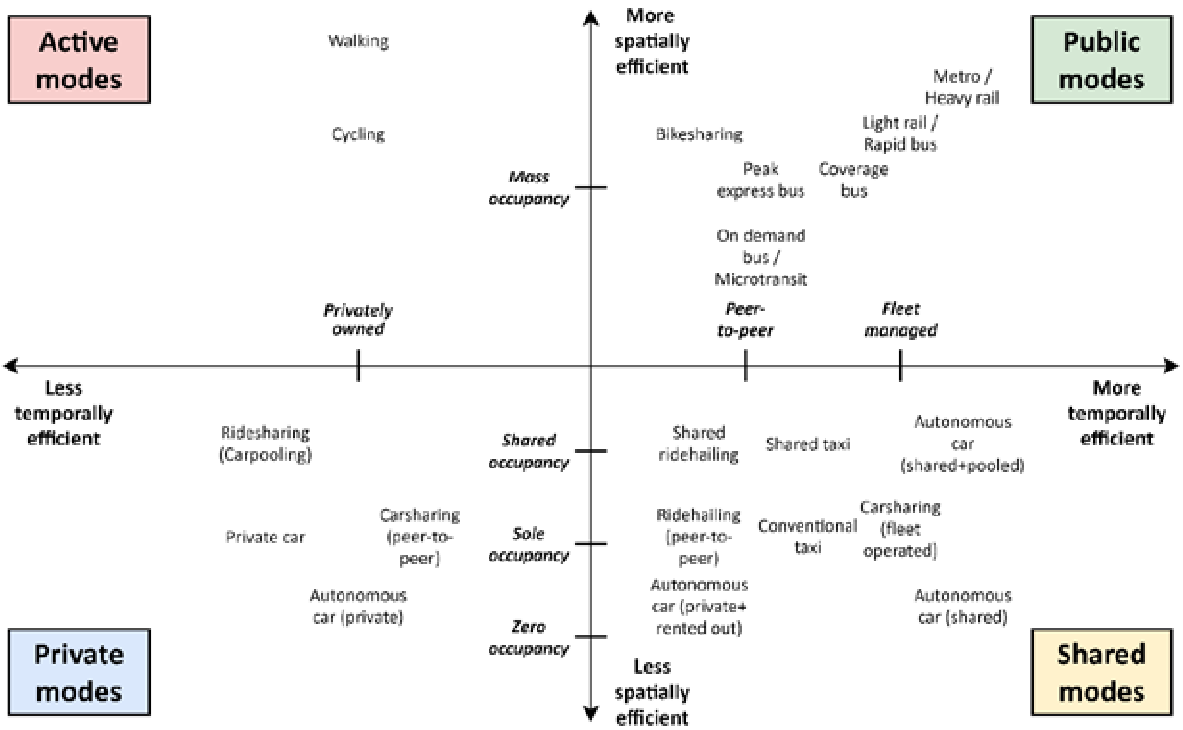

Figure 5: The modal efficiency framework situates public, private, active and shared (or new mobility) modes with respect to their spatial and temporal efficiencies (Wong et al., 2020)

MaaS brings together ***all temporally efficient modes across a range of spatial efficiencies***. The question, therefore, is how best to integrate across these spatial scales and deploy the most appropriate mode in each spatial-temporal setting. This necessitates a re-evaluation of transport integration. Modal integration can help ensure that the transport system is efficient network-wide, not just efficient within a single mode or operator.

Sustainability and mode shift

The societal and sustainability benefits of MaaS are derived from being able to 'nudge' travel behaviour towards more temporally and spatially efficient modes. The integration of discrete modes and the provision of innovative pricing models can help in this regard (a concept to be introduced as 'bundles' in the next section). However, there also exists the risk that MaaS can enable existing public transport users to more readily replace trips with shared modes like ridehailing—particularly in short trip situations and where multiple people travel together (e.g., in a family) where TNC travel may be price competitive. [2] This can have downstream impacts on traffic congestion and the financial sustainability of public transport. In fact, many TNCs have built their initial business models on competing with public transport (see Appendix A2 for an evidence base)—though many now find more value by collaborating rather than competing. Wong et al. (2020) argue that a governance overlay is required to set parameters of operation so that the outcomes of MaaS is consistent with societal objectives for a more sustainable transport ecosystem.

COVID-19 and MaaS

The ongoing coronavirus pandemic has reset the public's expectations around transport and commuting, as biosecurity becomes a new attribute in mode choice. Mixed messaging from government and politicians and the stigmatisation of public transport can cause lingering impacts on the public's willingness to share physical space. This can be coupled with apprehensions around sharing, which have already been exhibited, particularly in smaller vehicle environments (Dolins et al., 2021), and often with gendered and demographic patterns.

The financial sustainability of operators, especially commercial operators (namely TNCs), can also be of concern (Wong, 2020). A turnover of bikesharing operators has already been exhibited (due mainly to unsustainable growth at all costs), whilst further financial challenges can lead to consolidation in the market and less appetite for growth or desire to serve thin markets like the urban periphery. The rise of remote work and reduced commuting requirements for white-collar workers may also place pressure on services that have been designed around the CBD commute. Network reform is required and greater operational agility to meet changing travel needs, mainly as movement restrictions come and go.

One of the realities of the new paradigm is also the importance of personalisation and record-keeping to assist contact tracing efforts. TNC services provide excellent tracking functionalities, with technology-enabled mobility even expanding into the realm of public transport through mobile ticketing systems and smarter journey planners.

The nature of uncertainty means that is it incumbent upon the government to undertake fail-safe investments which remain agile and flexible and able to meet the requirements of the likely (as well as unexpected) scenarios governing the future of cities, the need for travel and the nature of this travel. Many committed big-ticket infrastructure projects were built on assumptions that have now changed and have not (yet) been subject to re-review.

Investments in services that respond to innate deficiencies in accessibility and help improve equity and mobility (Chapter 4 presents this analysis for Melbourne) can bring value regardless of the future strength of CBDs and other major activity centres. Enhancing the freedom of the travelling public can bring value irrespective of people's future behaviour and in spite of the unpredictability of transport modelling in these times (Walker, 2018). Anticipating the unintended consequences of new technologies is also valuable (Currie, 2018), such as investing in ways where vehicle assets need not be privately owned (especially problematic with the advent of autonomous vehicles due to zero-occupancy deadheading and the associated higher vehicle kilometres travelled). The "as a service" basis of MaaS is very much consistent with this vision and therefore remains of relevance in a future world.

[2] Note most public transport fares are usually regressive—i.e., the unit cost per kilometre reduces for longer journeys.

2.3. Bundles, budgets and brokers

A major theoretical contribution around the design and implementation of MaaS may be related to the *three Bs,* "budgets, bundles and brokers" (Hensher, 2017: 91). These concepts have formed the foundation around the development of MaaS propositions.

Bundles: What transport modes are packaged together and their package format

Under MaaS, customers purchase MaaS bundles which grant them a defined volume of access to each mode (or modal family[3]), each with a specified level of service (for example, pickups within five minutes). This is similar to telecommunications plans which bring together different services like calls, text and internet access. The quantity of each mode might be defined in terms of hours or kilometres of service. The mobility packages may be tailored by age, occupation or location to suit different market segments and enable providers to cross-subsidise between mobility options or practise price discrimination. Bundling is a mechanism to repackage existing services together with new services to create a more attractive way for people to access mobility.

As part of an integrated package, one of the most contentious issues is the comparative merits of **pay-as-you-go (PAYG)** as compared with **subscription** models (over a fortnightly or monthly period, for instance) of selling integrated mobility bundles. Differing evidence has emerged on the popularity of each, including through stated choice investigations in Australia (Vij et al., 2018, Ho et al., 2018), though preference is often dependent on the design of subscription plans and the discounts built-in as part of the MaaS offering.

One of the key considerations is how PAYG and subscription plans relate to the business model of the MaaS service provider. The original concept is for a MaaS business to purchase transport capacity in bulk and thus negotiate to obtain quantity discounts. They are able to finance this with customers pre-paying for their mobility credits, and based on the assumption that some of these credits remain unused at the end of each subscription period (e.g., phone plans)—all whilst passing on a small proportion of the original discount to the consumer. The difference between what is charged to the end-user and the price of trips taken constitutes the gross profit for the MaaS broker at its purest (Le Vine, 2011). If PAYG is indeed the preferred approach, then what is the value add for the customer beyond a better journey planner? It also calls into question why the user might pay for something they have always had for free—i.e., a journey planning application, although these are often supported by advertising, and the best applications utilise a freemium model. In many cases, customers are even required to pay a subscription fee just for the privilege to join a MaaS platform as a PAYG user. Whether customers derive benefit from this remains unclear.

Budgets: How modes are packaged together and their pricing

Importantly (and as alluded to in the previous section), bundles (in combination with their pricing, or budgets) can be used to influence travel behaviour. In the example of the Sydney Tripi MaaS trial (Ho et al., 2021), the subscription bundle Green Pass was provided (Figure 6), which offers unlimited public transport (Opal) trips, plus $3 off every Uber/taxi ride—providing an attractive short distance discount (more than in the case of a percentage discount in relative terms). Subscribers of the Green Pass were hypothesised to use public transport for longer journeys (given sunk costs) and Uber/taxi as a short first/last mile feeder to take advantage of the offer. This was, in fact, the

[3] This might be the case for public transport where many existing implementations have considered different public transport modes (e.g., bus, train, ferry, light rail) as a single mode.

behaviour exhibited (and encouraged), paying homage to the role of subscription plans in nudging travel behaviour (not otherwise possible via PAYG).

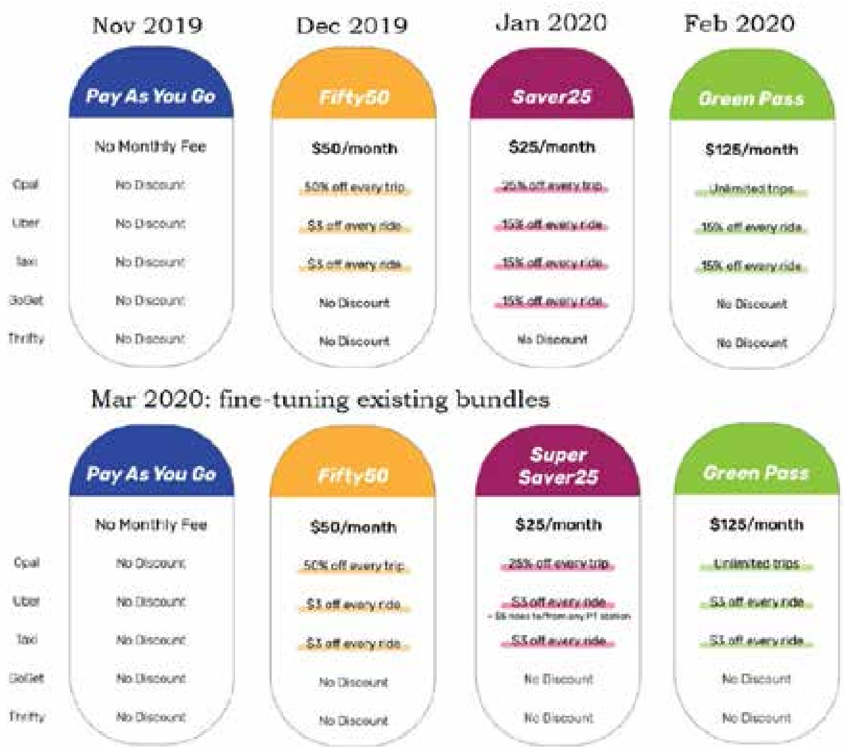

Figure 6: Examples of bundles (PAYG and subscription) provided in the Sydney Tripi MaaS trial

According to Jang et al. (2021), MaaS contributes to improving sustainable transportation in a non-linear manner as a function of decreasing monthly subscription fees and/or increasing the subscription length. A separate example of Queensland's ODIN PASS bundles (offering both PAYG and subscription plans) is provided in Appendix A3.

Market testing MaaS is related to the concept of budgets in terms of the need to elucidate the preferences of all stakeholders, including demanders and suppliers in the MaaS ecosystem. Stakeholder ideation of service delivery is critical (undertaken in Chapter 6), but so too is aligning with what customers desire and ensuring that MaaS to designed as a response to solving transport problems. A major focus of this report is to understand the inherent need in Melbourne for multimodal connectivity (undertaken in Chapter 4) via accessibility analysis and customer surveys.

Brokers: Key players in the MaaS ecosystem and how integrated services may be delivered

MaaS sees the likely emergence of mobility brokers (also known as aggregators or integrators), which bring together specialised businesses and value add by offering an integrative function. Brokers form the conduit for connecting demanders of transport service and suppliers of the transport capacity by facilitating the delivery of physical transportation.

Central to MaaS is the establishment of a new business model which is built on the integration of different and detached services, including commercially-driven new mobility modes and public transport, which are either very low margin or financed through public subsidies (Figure 7 offers a Finnish example). Wong and Hensher (2021) analysed the conditions around which the identified mode-specific operators and non-mobility providers (including providers of the technology platform and investors) might wish to collaborate. Section 6.3 provides a more thorough identification of relevant stakeholders and undertakes solution ideation in collaboration with industry in the context of Melbourne.

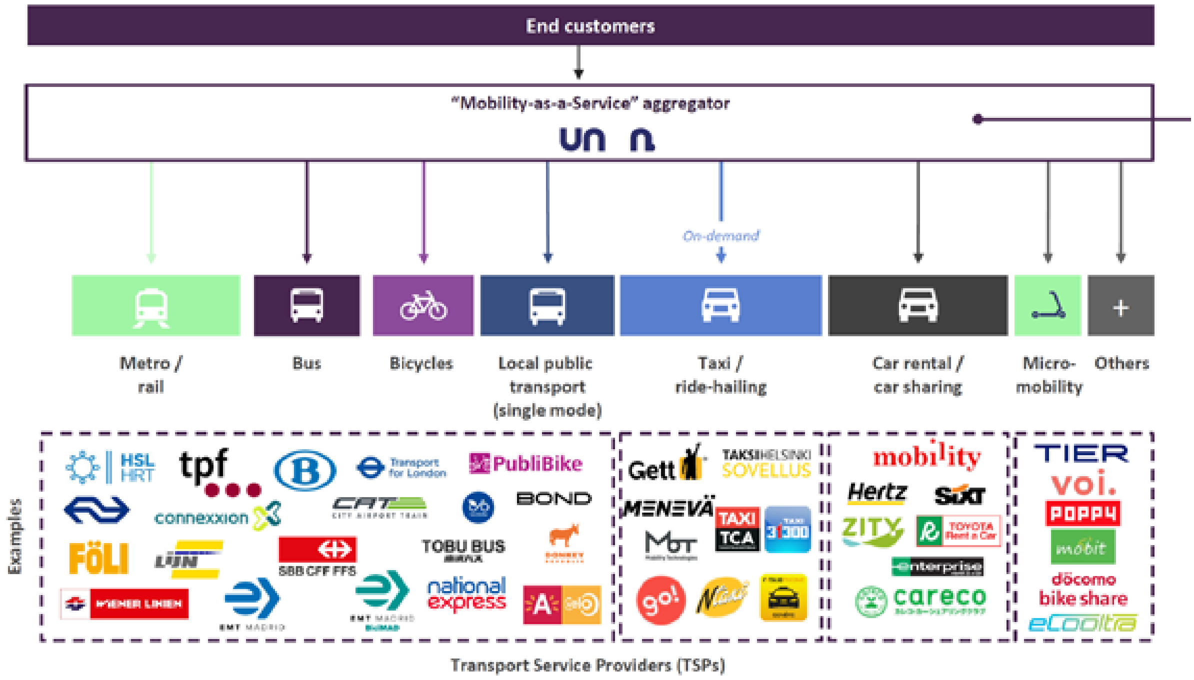

Figure 7: Finland's MaaS Global broker/aggregator (operating as Whim), bringing together a plethora of transport service providers

2.4. MaaS in Australia

The preceding three sections summarised the theoretical antecedents for MaaS, providing an overview of definitions, objectives/rationale, as well as three core components necessary for implementation in terms of bundles, budgets and brokers.

Following Finnish footsteps and other Northern European trials/pilots, Australia has been embarking on efforts to realise these MaaS aspirations. The government sector in Australia has established various initiatives, primarily at state levels. The MaaS Program Management Office set up and reporting to the Director-General in Queensland's Department of Transport and Main Roads (TMR) is leading policy reform in the state. In NSW, MaaS forms an essential cornerstone of the *Future Transport 2056* agenda and has been operationalised via (amongst other policy initiatives) the *MaaS Innovation Challenge*.

Peak bodies and associations such as Austroads and ITS Australia have led research and industry engagement programs, as well as advanced advocacy around common data standards, regulatory harmonisation and the need for an open data marketplace.

Table 3 documents the location of Australian MaaS schemes, their operational status, number of modes and integration level as defined by the Sochor et al. (2018) service-based typology. The MaaS schemes in Australia may be grouped into three categories, each with a different level of integration: (i) Full MaaS research trials, (ii) extended third-party journey planners, and (iii) public transport smartcards which provide TNC service payment (and discount) functionalities.

MaaS research trials

Perhaps the most notable and comprehensive MaaS implementations are research-based trials that have caught worldwide attention in the academy. Sydney's Tripi trial and Brisbane's ODIN PASS[4] represent innovative collaborations between universities, the private sector and government, brought together (with matching funding) from the iMOVE cooperative research centre. These two trials are the most comprehensive in terms of the number of modes and level of integration (the only ones which incorporate bundles and subscription plans). Both have a high focus on understanding travel behaviour and willingness to pay (through revealed and stated preference surveys). However, because their platform development and bundle discounts are subsidised by research partners, the ability to offer MaaS as a commercially viable proposition remains in question.

Extended journey planners

As third-party vendors, both RACV's Arevo and Carsales' Placie have their genesis in Melbourne. With roots in a motoring club, Arevo offers more advanced driver-related capabilities, including the ability to track petrol prices and identify parking locations and vacancies (where available) through a partnership with UbiPark. A deep link to Flexicar offers carsharing services whilst grade-by-grade cycling infrastructure is presented in the base map. However, no integrated payment functionalities are provided.

Placie is a newer offering with highly detailed fare/payment information. Preferences may be set for "quick" or "cheap" trips, depending on user preferences. The multihoming of taxis and ridesharing is available, bringing together the operators Ola, Silver Top, Black & White, and13cabs. Public transport trip payment has not yet launched, though the feature is reportedly being developed.

Transfer discounts

Sydney's Opal smartcard ticketing system (launched in 2013) is the newest to be implemented in Australia, though Queensland has subsequently embarked on a next-generation GoCard, whilst Melbourne plans to develop new Myki functionalities. The Opal system offers sophisticated abilities to use contactless bank cards for payment on the gate infrastructure or a digital (mobile) Opal card, as well as providing an open ticketing ecosystem that allows third-party service providers to 'plug in' to the Opal payment system.

Opal Connect allows transfer discounts to be offered for public transport connections to government-sponsored demand-responsive services (which exist as a separate 'mode' in terms of fares charged). Digital Opal (which had its genesis in the *MaaS Innovation Challenge*) is now permitting Uber ridesharing, Lime e-bikes, Inogogo taxi and Manly Fast Ferry (all private operators) customers to pay using Opal and thereby enjoy a transfer discount. Note that these constitute sharing of the fare payment mechanism only, without integration of the journey planning/information interface.

However, are transfer discounts considered MaaS? Whilst they do not meet definitions (meeting level 2 payments but not level 1 information), they are captured for the purposes of this report due to the interest in integrating public transport and TNC services.

[4] ODIN PASS is short for "every Origin and Destination IN a single PASS", an apt description of MaaS.

Table 3: MaaS-type schemes in Australia, their status and level of integration

Category	**MaaS Lite**				**Full MaaS**	
Characteristics	Journey planner		Transfer discount		Planning to payment	
Product name	**Arevo**	**Placie**	**Opal Connect**	**Digital Opal**	**Tripi**	**ODIN PASS**
Location	Melbourne	Melbourne	Sydney	Sydney	Sydney	Brisbane
Status	Operational	Operational	Operational	Trial	Trial	Trial
Launch	Early 2019	Late 2020	Late 2019	Jul-Dec 2021	Nov 2019-Mar 2020	Jul 2021
Number of modes [5]	4	5	2	5 (2 at a time)	5	5
Level of integration (from Sochor et al. (2018))	1	1	2	2	3	4
Core offerings	Information-only	Information-only	Payments-only	Payments-only	PAYG and subscription bundles	PAYG and subscription bundles
Platform provider	Intelematics (formerly SkedGo)	SkedGo	Cubic [6]	Uber, Lime, Ingogo Taxi, My Fast Ferry	SkedGo	SkedGo
Commercial impetus	RACV-funded; desire to expand into multimodal mobility, opportunity to on-sell related products like home insurance	Carsales-funded; significant venture capital support	Government-funded; supporting on-demand utilisation	Operator-funded; part of Transport for NSW (TfNSW) *Future Transport Technology Roadmap 2021-2024*	iMOVE cooperative research: University of Sydney, Insurance Australia Group (IAG)	iMOVE cooperative research: University of Queensland, Queensland Department of Transport and Main Roads (TMR)
Additional functionalities	Petrol prices, parking stations	Multihoming of taxis/ridesharing			Research project (ex-ante/ex-post surveys)	Research project (ex-ante/ex-post surveys)
Notes	Reduced Myki functionality	Popular amongst younger demographic	Genesis in on-demand integration	10,000 eligible customers only	Trial amongst 150 IAG employees	All UQ staff and students eligible

[5] Public transport is considered as a single mode (excludes walking)
[6] Functionality is provided by Opal gate infrastructure and the payment token

2.5. Lessons for MaaS success

The nature and extent of MaaS implementations within Australia reveal several lessons around what is possible in the present marketplace. The three groups of MaaS schemes reveal:

- Government-sponsored schemes are dependent on private partners who operate and supply the technology interfaces (and their design and implementation might be influenced by private-sector interest). There is a requirement that the public transport smartcard system is sufficiently advanced, adaptable and open. The ticketing vendor often charges large amounts for system upgrades (a vendor lock-in issue).
- The ability for third-party vendors to attract partners and integrate services is critical. Their ability to integrate beyond information and into payments and subscriptions may often be limited (particularly when dealing with the rigidities of government and public transport information systems). Third-party vendors need a commercial impetus to invest in the integration platform; this could be via the opportunity to on-sell non-transport services. A multiservice MaaS ecosystem may hence likely bring financial benefits.
- Research-led schemes were also hampered by rigidities in the public transport ticketing systems (although temporary workarounds may be possible where the authority is also a partner). One major challenge in ensuring a financially viable business model, and neither Tripi nor ODIN PASS would have been possible in the absence of research collaboration and funding support.

MaaS needs to be implemented in a way that shows value for both sustainability and profitability to secure buy-in from government and business. The MaaS schemes in Australia provide vital lessons for this effort, as well as helping inform a series of success criteria for MaaS. This is akin to a MaaS readiness concept, with a diagnosis for Melbourne provided in Section 6.2. These key requirements surround user demographic, behaviour, service availability, technology, data sharing, government policy and risk appetite.

The integration ideals surrounding MaaS presented in this chapter can be characterised as a continuation of an integration story many decades in the making. The integration ambitions of MaaS may be situated within a Melbourne-specific discussion, with reference to the policy reform context, as well as how the advent of new mobility modes might draw parallels with historical developments, but now (critically) drawing on new technologies which can better aid coordination and integration efforts.

3. The Melbourne context

3.1. Policy and service reform history

The desire to integrate has been a recurring motif through Melbourne's public transport reform and policy history. Servicing a sprawled metropolis with thinly spread demand and retrofitting services into auto-centric communities which were not built to be conducive for public transport are particularly challenging (Mees, 2010).

MetPlan: Metropolitan Public Transport Industry Plan (MTA, 1988)

MetPlan built on the groundwork for an integrated public transport system in Melbourne. The establishment of the Metropolitan Transit Authority (MTA) earlier in the decade brought together trains, trams and buses, and introduced a new gross cost contractual basis where the authority took on the revenue risk and collected fares to allocate back to operators as per an agreed formula. This was accompanied by the establishment of The Met as an operating division and the introduction of the MetCard as one (zonal) ticket, which placed Melbourne as a national leader in terms of providing mode harmonisation in fare policies—a feature that other cities (e.g., Sydney) struggled to implement even two decades later.[7]

MetPlan featured frequency standards for trains and buses and proposed a network of orbital routes—despite these not been implemented (and service levels even cut in the early 1990s). The subsequent privatisation experience in 1999 with two train and two tram operators resulted in a fragmentation of wayfinding and customer information. Not only was there no active system-wide branding or marketing in place, but operator-specific tickets were even introduced, which further complicated the ticketing system and led to wasteful competition between modes (Mees, 2005). The Metlink umbrella brand was subsequently introduced in 2003 (in regional Victoria, this was called Viclink) to provide a single identity for Melbourne's public transport system. Whilst the primary focus was on marketing, the agency published timetables, maps and operated a multimodal website and journey planner, as well as centralising customer feedback, market research and lost property functions.

The Metlink and Viclink brands were subsumed by the establishment of Public Transport Victoria (PTV) in 2012 (which subsequently came under the Department of Transport in 2019). PTV continues to remain a public-facing brand, whilst the smartcard ticketing system Myki was introduced fully in 2010, replacing the Metcard magnetic stripe system.

Meeting Our Transport Challenges (Victorian Government, 2006)

Network reviews showed that Melbourne provided poorer service levels than even smaller cities like Adelaide and Perth (particularly for buses). *Meeting Our Transport Challenges* (MOTC) proposed introducing minimum service standards to bring at least an hourly service to most areas until 9 PM, seven days a week. The plan proposed a new series of cross-town orbitals (named SmartBus[8]), which provide high-frequency, circumferential bus links to complement the radial rail network. Complete with extensive bus priority investments (much of which was later dismantled), a

[7] Even today, smartcard systems like Opal in Sydney is a new ticketing system on the same fragmented fare structure. An improved system would have: (i) a consistent way of measuring distance between modes, (ii) consistent fare bands, (iii) consistent fare levels between modes, and (iv) consistent transfer policies.

[8] This builds on the SmartBus concept demonstrated in Melbourne's east (Blackburn, Springvale and Warrigal Rd), where service improvements led to a 30% patronage increase.

real-time information system, and a premium branded bus fleet, the SmartBus program continues to be one of the largest single (systematic) investments in the bus network Melbourne has ever seen.

MOTC also established the Principal Public Transport Network (PPTN), of which SmartBus played a constituent role as part of the network. The plan focused on providing access to the PPTN via local buses, park and ride, and local access initiatives. This included consideration of demand-responsive transport where demand was too low for a conventional fixed-route service to be viable. A capacity program to meet growth in the metropolitan fringe was also earmarked.

Importantly, MOTC asserted that *"more than 90% of households in Melbourne are now within 400m of a public transport service"* (Victorian Government, 2006: 17). This is a hypothesis that is repeatedly called into question (and further investigated in this report). The MOTC priorities, including establishing minimum accessibility levels, providing high-frequency trunk (gridded) services, and the focus on improving access to these trunks, are timeless and remain central to supporting the ideals of improved first/last mile connectivity sought in this project.

Transport Integration Act 2010

The *Transport Integration Act 2010* (the Act) is the prime transport statute [9], bringing together a vision, set of objectives and decision-making principles for integrated and sustainable transport in Victoria (Appendix A4 provides a summary of the Act). The focus on integration in a legislative context (the most powerful policy tool) is unique in Australia and provides greater Parliamentary scrutiny and review opportunities. Importantly, the Act recognised the role of non-transport (interface) bodies such as planning authorities and municipal councils in achieving transport outcomes. However, as an "aspirational framework" (as opposed to a facilitative or coercive legislation), the Act is largely symbolic and only asks that transport and interface bodies "must have regard" to the Act's policy framework (Pearce and Shepherd, 2011). This is a significant weakness in the Act's implementation due to the reliance on judgement, common sense and self-enforcement. Further to this, the Act, in its development, did not envisage the entry of TNC or application-based service providers that have since proliferated (although it did consider "commercial" road and rail transport as distinct to "public transport" on road and rail).

The Victorian Auditor-General's Office undertook an assessment (VAGO, 2021), tabled in mid-2021, on whether the Department of Transport complied with requirements under the Act. The review found extreme fragmentation under 40 different plans and strategies. Even in combination, this did not provide a coherent, comprehensive, nor transparent transport plan (with most plans not being publicly available). Proposals by the bureaucracy to the political level were not built on the Act's requirements and tended to focus on individual modes rather than the system as a whole. Many reform opportunities associated with the state's record investments in new infrastructure (e.g., Big Build projects) were missed, along with the necessary alignment with Victoria's Living Transport Network framework.

The Act and audit also do not yet take a broader (mode-agnostic) view of public transport which incorporates commercial TNC-provided new mobility modes.

[9] The Act replaced the previous *Transport Act 1983*.

Victoria's Bus Plan (Department of Transport, 2021)

One of the mode-specific plans of late is *Victoria's Bus Plan*. This represents a substantial focus on the bus industry on a backdrop of patronage stagnation, in which pre-pandemic stood at 120 million passengers per year (versus 200 million for trams with a far smaller catchment).

Victoria's Bus Plan is ambitious, aiming for 200 million bus trips per annum by 2030. That represents around 5% annual compound growth (at least double Melbourne's pre-COVID annual population growth). There is a substantial focus on technology (such as zero-emissions buses), but these generally do not impact service quantity and *usefulness* to people. The plan specifies necessary service design directives. Figure 8 shows the tiered service offering proposed, though proper definitions (service frequency and span) remain absent. The plan also provides a limited focus on how the bus network interacts with other public transport and new mobility modes.

NEW BUS ROUTE CATEGORIES

Category 1 — RAPID ROUTES

Bus Rapid Transit (BRT) routes will deliver faster, more frequent and more reliable journeys on busy public transport corridors. They will be characterised by extensive on-road priority, premium stop infrastructure and a rail-like experience for passengers. The Doncaster Busway will be Melbourne's first dedicated busway – providing separated lanes for buses along the Eastern Freeway.

Shuttle Routes will provide direct point-to-point service, connecting rail stations with universities and other high-demand destinations. They will be characterised by dedicated lanes and a limited number of stops with frequencies, operating hours and stop spacing carefully designed to respond to the market for which the service is being designed.

Category 2 — CONNECTOR ROUTES

Trunk routes will connect suburbs to key transport nodes and employment and shopping centres. Services are frequent and direct and will feature road priority measures, including bus lanes, where feasible. Trunk routes will normally operate in mixed traffic and provide greater integration with homes and destinations.

Connector routes are the basic building blocks of urban transit. They provide easy access to the rail network as well as local employment and shopping centres. These services balance route directness with the need to provide catchment coverage of residential suburbs. Diversions are minimised to ensure competitive travel times and to attract passengers away from private vehicle use.

Neighbourhood routes offer greater access while being as direct as possible and providing coverage. Services are low frequency and have a shorter span of hours but are often strongly patronised.

Category 3: — LOCAL ROUTES

Local routes provide local access for passengers. These services are targeted to provide a minimum level of service to enable access to nearby shops and services.

Demand responsive transport will be trialled initially in two primary contexts - areas of low demand where regular bus services might not be efficient and in growth areas where road networks are still developing and communities are in the process of settling.

Category 4 — SCHOOL ROUTES

School routes meet the demand spike created mostly by high school students travelling to and from school. School services can be unique routes that otherwise wouldn't generate demand.

Figure 8: Tiered bus service hierarchy from Victoria's Bus Plan (Department of Transport, 2021: 11)

3.2. What's old is again new

The need to integrate remains an elusive desire as customer demands increase. What was once innovative with the integration of fare systems between trains, trams, and buses has now been surpassed by the arrival of new TNC modes and technologies that can help provide better information, payments, and experiences. Integration is an ongoing journey, and the aspirations of MaaS presented in Chapter 2 represent the next frontier.

Historical legacies in network planning

One major challenge is path dependency in bringing together historically fragmented bus operations. Non-subsidised, small family operators began to be regulated in the 1970s with fares, ticketing and operating subsidies provided by the government. There have been ongoing efforts to consolidate operators (including with the arrival of multinational players through acquisitions), but this can sometimes embed network inefficiencies. Historic depot locations and the fragmentation of routes along territorial lines can result in higher dead-running and poor operational agility. An example is at railway stations where different 'sides' continue to be operated by different operators (reducing network effectiveness and customer outcomes).

Recently, there has been some emergence of better-coordinated network planning with the centralisation of service planning functions and even the advent of industry joint ventures (e.g., for SmartBus services where peak vehicle requirements can be 100+ vehicles and using multiple operators and depots). However, this happens on an ad hoc basis and is an exception rather than the rule. More systematic and comprehensive programs that continually improve service design is required.

Bringing integration from public transport to encompass new mobility modes

Section 3.1 discussed the policy and service planning reform history in Melbourne within public transport (contracted) modes. Table 4 presents how key milestones from Victoria's service reform and policy history align with different levels of MaaS integration, albeit within the context of public transport modes (trains, trams and buses). The challenge in a MaaS setting is to bring together TNC-provided new mobility modes into the same ecosystem.

Table 4: Melbourne's service reform history and key milestones (integration criteria)—built on the Sochor et al. (2018) typology

Level of integration	Public transport (train, tram, bus)	New mobility modes
(4) Societal goals	Yes (embedded)	None
(3) Service offer	Metcard periodical, Myki Pass	None
(2) Booking/payment	Metcard, Myki Money	Placie (partial)
(1) Information	The Met, Metlink/Viclink, PTV	Arevo, Google Maps
(0) Physical services	SmartBus, Big Build projects	*Entry from the 2010s*

Manual coordination efforts

Public transport operations were once more manual and less automated. There was an era where services would be held to await connections. This was easier in smaller operations with limited service frequency and where a "*one bus, one shift, one driver*" mentality prevailed. Larger and more complex operations mean that personalised services are less scalable. The centralisation of more service planning functions and definition of key performance indicators (e.g., on-time running) means that holding services for delayed trains is no longer feasible. Operators could even be penalised under existing contractual regimes.

However, there is a move towards trialling better multimodal connectivity via a manual operationally-led approach. The Kilmore and Wallan trials, which began from October 2020, saw Link Buses wait up to 20 minutes for connecting V/Line services to arrive. This initiative is active from the PM peak to the last service on weekdays only. One issue is how scalable such an initiative could be, particularly as it impacts other runs (including connections), as well as bus customers who are not joining from the train service.

Rapid Running on Route 246 (Elsternwick to Clifton Hill via St Kilda) is another example where strict timetables (and on-time running as a *process* goal) may be forgone in the name of better end-user outcomes by allowing early running to reduce dwells and to speed up journey times in highly variable traffic conditions (on the notorious Punt Rd). Ideally, in this scenario, the focus should not only be on trip start times but also to maintain headway regularity (by leveraging onboard technologies to actively manage headways) throughout the length of the route.

Demand-responsive transport (DRT)

Another case of initiatives returning from a bygone era is demand-responsive transport (also known as on-demand). In the 1960s/70s, these were known as “unconventional modes” or “ dial-a-ride”—hailed as a futuristic and novel form of transport. Melbourne pioneered DRT in the form of the TeleBus, which serviced the outer eastern suburbs—amongst which the Rowville service has now been upgraded with a technology platform and rebranded as FlexiRide. One of the common issues in the past has been the manual labour requirements for booking and routing necessary to operate such a personalised form of transport.

In recent years, there has been a resurgence of the DRT concept, aided by new technologies. In many cases, there is an obsession to ‘uberise’ fixed-route bus services for flexibility’s sake. One of the key issues of DRT enduring relates to clarity—both in terms of purpose and the cost of providing the service (or, more accurately, its relative cost as compared with an established baseline). A major difficulty is in defining what this baseline subsidy rate (the counterfactual) and what increase in costs can be acceptable. Usually, this is a fixed route bus service that the DRT replaces, or more bespoke community transport or special needs services which often have an independent funding stream/mechanism.

Lessons drawn from global research shows that most DRT services fail (Currie and Fournier, 2020). There is a need for better clarity in terms of the rationale/objectives of a DRT service, which are likely to vary according to different spatial contexts (rural/suburban/urban) and end-user markets (e.g., commuters, elderly, students) being targeted. As a normative determination, this is often at risk of being politicised, leading to criticism and can result in government apprehension in the use of public funds. DRT thereby becomes even more difficult to scale and makes sense only in specific (and limited) use cases.

Micromobility and active travel modes

Largely forgotten in the motorised era is the important and vital role of active mobility. Around 60% of all motorised trips (including first/last mile trips to high capacity public transport) are just 5 miles or less (CB Insights, 2019), lending themselves to be perfectly replaceable by ‘slow modes’ such as walking and cycling. The advent of battery technologies has enabled mobility devices like bicycles (either by peddle assist or throttle) to become a more accessible modal option without terrain or weather (i.e., heat) being a hindrance to their use. Powered e-mobility devices can be an attractive alternative to the car for short-distance travel with limited travel time disadvantages and significant environmental and amenity benefits.

Many powered micromobility vehicle designs have entered the market (Table 5), with e-bikes and e-scooters most prevalent. **Powered standing scooters** have recently been legalised by most state and territory authorities, following the National Transport Commission's recommendation to consider the barriers to the safe use of personal micromobility devices (NTC, 2020). Victoria is presently embarking on a program to trial these devices on public roads.

Table 5: Types of powered micromobility vehicles, defined by key characteristics (SAE International, 2019)

TYPES OF POWERED MICROMOBILITY VEHICLES[1]

	Powered Bicycle	Powered Standing Scooter	Powered Seated Scooter	Powered Self-Balancing Board	Powered Non-Self-Balancing Board	Powered Skates
Center column	Y	Y	Y	Possible	N	N
Seat	Y	N	Y	N	N	N
Operable pedals	Y	N	N	N	N	N
Floorboard / foot pegs	Possible	Y	Y	Y	Y	Y
Self-balancing[2]	N	N	N	Y	N	Possible

[1]All vehicles typically designed for one person, except for those specifically designed to accommodate additional passenger(s)
[2]Self-balancing refers to dynamic stabilization achieved via a combination of sensors and gyroscopes contained in/on the vehicle

3.3. Metropolitan fringe issues

Of particular interest in this study are metropolitan fringe communities, which have a predominately auto-centric urban structure and have traditionally been underserviced by public transport. These suburban 'greenfield' developments are some of the fastest-growing communities in Australia (ABS, 2021). These communities are typically lower socioeconomic status, at risk of social exclusion and spend significant household budgets on car ownership (typified by transport poverty).

Social exclusion

Poor public transport availability leads to forced car ownership and associated pressures on household budgets and social exclusion (including the ability to hold employment) for those without car access (Currie and Delbosc, 2013). Households may need to buy an extra car largely just for the commute to the railway station, thereby exacerbating transport poverty. Often, there is also a high degree of carsharing within household members, especially for young people (Delbosc et al., 2015), as well as a reliance on lifts from other household members (Bell and Currie, 2007), all constraining the freedom of movement.

Service productivity

Public transport services, where provided, are often established years after residents have moved in. This comes at a time when residents would have already made initial decisions about car ownership and mode choice. This is one reason (and a process of cumulative causation) for causing new bus services to greenfield estates to perform poorly in terms of patronage. This, in turn, may lead to a limited appetite to improve services.

Infrastructure Victoria regards 20 passenger boardings per bus service hour (i.e., roughly 1 passenger boarding per kilometre given average bus speeds) as a minimum threshold for a bus route to be considered productive. Around 40% of metropolitan bus services currently do not meet this threshold, with poor performing routes most likely found on the urban fringe in Melbourne's north, east and south-east (Infrastructure Victoria, 2018).

Access to rail services

Melbourne's radial rail network provides the only source of frequent public transport in much of the urban periphery (this is supported by empirical analysis in Section 4.2). Access to rail stations has been an ongoing challenge, with feeder buses either lacking or infrequent. Newer communities are now better served by active transport networks, but longer distance access/egress travel can still be unattractive. In most cases, the private car remains the preferred option for travel to train stations (confirmed in Figure 17, and particularly acute for Zone 2 stations).

One popular approach has been the targeted provision of station parking, which (in non-pandemic times) has been inadequate and difficult to scale. Building car parks can be controversial and extremely expensive (Table 6), and their effectiveness is often questioned. In greenfield parking locations, around one-third of car parking users previously drove their entire journey, whilst the other two-thirds switched from the bus, cycling or walking to the station. This zero-sum game in terms of cannibalising feeder bus and active transport use is rarely appreciated.

Table 6: Benchmark construction costs per parking space (ANAO, 2021: 73)

Scenario	Cost range per space	Average cost per space
At-grade	$11,900-$40,120	$26,700
Multi-storey standard (brownfield)	$18,400-$44,500	$28,800
Multi-storey adjacent to rail line (brownfield)	$26,800-$45,800	$39,600

The reality is that supporting other transport access modes may be a more cost-effective investment. Better feeder bus services and even subsidising TNC-provided new mobility modes, integrated via a MaaS interface, can be a more equitable, sustainable and effective solution in encouraging mode shift. An empirical investigation around the first/last mile problem in Melbourne and the barriers and facilitators for the choice of specific modes is conducted in Chapter 4.

4. Access as a barrier to public transport use

4.1. Measures of access and equity

Melbourne's public transport and land-use strategies have had an implicit focus on access. *Plan Melbourne 2017-2050* (DELWP, 2017) focuses on delivering a more compact city and 20-minute neighbourhoods, meaning that destinations need to be located close to where people live. Urban consolidation occurs along transport nodes and corridors because they have ready access to high-frequency public transport.

It is also known that people have a desired travel time budget. Marchetti's Constant (Marchetti, 1994) posits that people are willing to travel one hour (return) per day on average. People hence use quicker modes to travel longer distances. The ease of access to public transport is therefore fundamentally important to its usefulness, and by extension, people's propensity to use the service.

Why accessibility matters

Public transport service levels and mobility must not be considered in isolation but instead studied in the context of space (often termed accessibility). Accessibility may be defined as the ease of reaching destinations, such as employment, education, recreation, or other travel destinations. In fact, accessibility alone explains a large proportion of public transport mode share (R^2=0.61) (Wu et al., 2019a, Wu et al., 2019b).

Accessibility may also be considered in a more simplistic lens when studying the first/last mile. Accessibility may be simplified to refer to the ease of reaching the public transport network itself. It is helpful to define public transport as a subset of the entire network by considering the frequent network only. The ease of reaching this frequent network offers a turn-up-and-go travel option beyond the immediate vicinity. This may be termed "public transport accessibility".

Factors influencing public transport accessibility (the micro-level)

Public transport accessibility has both spatial and temporal dimensions. The spatial dimension may be considered in terms of catchments or access sheds. This is generally delineated as a diameter around which people are defined as being within walking distance. This is drawn as Euclidean (as the crow flies) distance but should more accurately be network distance (on what can be traversed by foot). Bus stops should be located at intersections to maximise penetration into suburban road networks.

An acceptable access distance for bus users is 400 m, but this can often be longer for light and heavy rail; more accurately, acceptable access distance depends on service levels, with frequency as the primary input variable. A study of bus stop spacing in 43 US cities found mean spacing to be 313 m (Pandey et al., 2021). Wu and Levinson (2018) investigated optimal stop spacings that maximise accessibility, noting that building more stops increases infrastructure and operating costs (reducing vehicle speeds and increasing fleet requirements that could otherwise be deployed on additional revenue services). Figure 9 shows how stop distance should increase as average bus running speeds rise to maximise total accessibility. These best practices are considered as part of the case study analysis in Chapter 5.

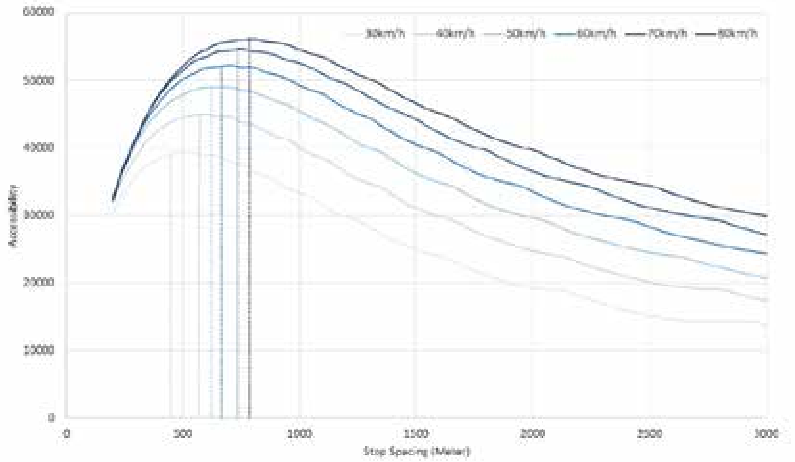

Figure 9: Maximising catchment accessibility for different public transport running speeds (Wu and Levinson, 2018: 8)

There is also a temporal dimension to public transport accessibility. The ease of walking to a public transport stop or station does not imply ready access to a public transport service. Unlike private vehicles, which are available on-demand as required [10], public transport operates to a timetable, and users often have to structure their livelihoods around it. This is particularly problematic where work and other commitments start and end at rigid times (e.g., appointments, shift work). Higher service frequency creates a network effect, and average wait times reduce to a point where it becomes negligible. When customers no longer rely on the timetable and can turn up and go for their next service, public transport becomes almost as ubiquitous as the way people's cars can be used on a whim. This 'tipping point' usually occurs at a frequency of 5 or 6 services per hour (headway intervals at 10-12 minutes).

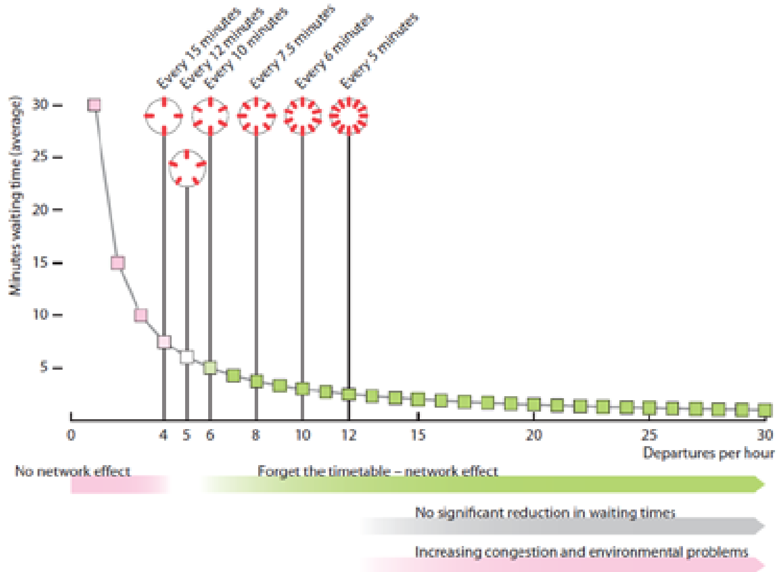

Figure 10: Networking effect arising from turn-up-and-go frequency (Nielsen et al., 2005a)

Finally, the span of operating hours is also important and can be a constraint to freedom of travel. Together, stops, frequency and span determine public transport accessibility at the micro-level.

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[10] An analogy is that we do not wait for our garage door to open once an hour so that we can use our cars. This is unlike public transport which is only available when it operates.

Public transport equity: A wicked problem (the macro level)

At the macro level, route and network design play a part in defining the coverage of an area. The traditional approach is to provide service by a measure of geographic area (equity per unit area or population). Through this, there is a case for lower-density suburbs to receive more service kilometres, as well as denser inner city environments where the population is higher.

An integrated approach provides service to areas of greatest need and patronage potential, taking into account land use and socioeconomic characteristics (equity per demand). Equity by demand can also be invariably subjective and also subject to feedback loops where poor service leads to higher automobile dependency and, therefore, less demand.

These three equity options are illustrated in Figure 11. A benchmark analysis should consider a unit area or population measure at the outset before imbuing other information and datasets via customer surveys or stakeholder analysis.

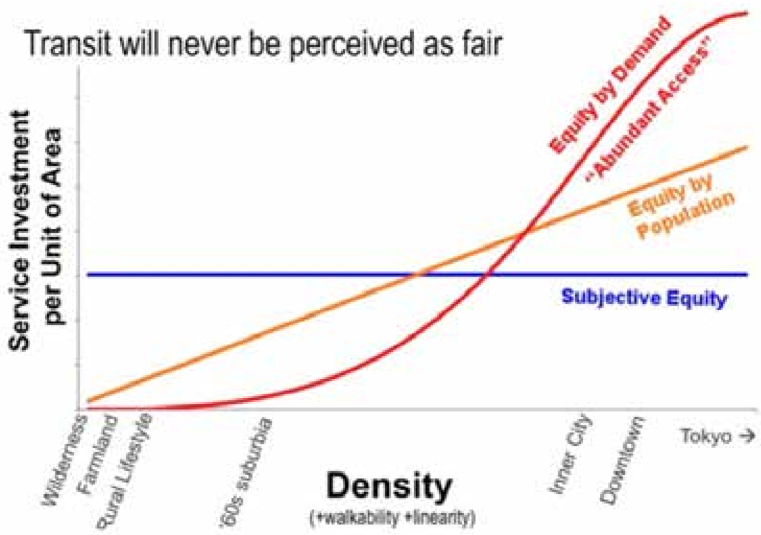


Figure 11: Different conceptions of equity in the provision of public transport (Walker, 2014)

4.2. Public transport accessibility level (PTAL)

To study public transport accessibility in Melbourne, the public transport accessibility level (PTAL) is used to provide an initial baseline/benchmark of service availability. Adopted by Transport for London in 2004 and now adapted by several jurisdictions abroad (including in Sydney[11]), PTAL is the gold standard measure for the spatial assessment of public transport connectivity.

PTAL maps accessibility by calculating the distance of any point to the closest set of public transport stops and stations, then overlays this with the service intensity at these stops and stations, as defined by service frequency. In doing so, PTAL outputs provide a comprehensive mapping of the first/last mile accessibility in a way that doesn't treat all public transport as homogenous but rather provides the added dimension of individuals' access to public transport as a function of its service level.[12]

[11] Details are published on the TfNSW Open Data Hub: https://opendata.transport.nsw.gov.au/dataset/ptal-public-transport-accessibility-level

[12] A frequency-based (tiered approach) for mapping Melbourne's public transport is available here: https://melbournetransportmap.com

The PTAL methodology

The public transport accessibility analysis was undertaken based on an adaptation (with minor modifications) of the Transport for London approach as outlined in Appendix A5. On a metropolitan Melbourne base map layer, the following two datasets were defined:

- **Points of interest (POI)**, showing where people live. These are established as mesh block centroids, the smallest Australian Bureau of Statistics (ABS) statistical unit consisting of 30-60 dwellings each. Analysis was not undertaken on an individual dwelling basis since this would be too computationally complex whilst bringing limited additional value.
- **Service access points (SAP)**, showing where public transport services operate. These include bus stops, tram stops and train stations. The service levels of SAPs are defined as service frequency in the AM peak (08:15-09:15), with data obtained from public GTFS feeds. In cases where stops are paired, the higher service frequency is taken (capturing the inbound direction).

The Haversine[13] distance between POIs and SAPs are then calculated. Only SAPs within a defined distance of each POI are included (640 m for bus stops and 960 m for rail stations, corresponding with walk times of 8 and 12 minutes). This reflects the long distances people are likely to walk to access higher quality services. The total access time for each POI is then calculated by combining with average wait times (half the headway), leading to an equivalent doorstop frequency. A weighting is then applied, reflecting the inherent reliability and attractiveness of different modes, leading to an accessibility index which is converted to a PTAL value as per Figure 12.

PTAL	Access Index range	Map colour
0 (worst)	0	
1a	0.01 – 2.50	
1b	2.51 – 5.0	
2	5.01 – 10.0	
3	10.01 – 15.0	
4	15.01 – 20.0	
5	20.01 – 25.0	
6a	25.01 – 40.0	
6b (best)	40.01+	

Table 2.2: Conversion of the Access Index to PTAL

Figure 12: How accessibility indexes convert to banded PTAL values (Transport for London, 2010)

[13] Haversine refers to the Great Circle distance between two points (as the crow flies). Use of network distance (via the road and pedestrian footpath network) can offer a more detailed representation of experienced distances but is more useful where POIs are defined on an individual dwelling basis. This is particularly useful in non-gridded street networks with poor connectivity (e.g., suburbia with cul-de-sacs and natural obstacles like parks and waterways).

PTAL values range from 0 to 6, with higher values representing greater public transport connectivity. A location exhibits a higher PTAL if (TfNSW, 2021):

- It is at a short walking distance to the nearest stations or stops
- Waiting times at the nearest stations or stops are short
- More services pass at the nearest stations or stops
- There are major rail stations nearby
- Any combination of all the above

Evaluating PTAL

PTAL values for each POI (mesh blocks) across Melbourne may then be mapped geospatially. Figure 13 shows the distribution of PTAL values across metropolitan Melbourne (more detailed sub-region maps are provided in Appendix A6). A number of key patterns are evident:

- There is significant heterogeneity in PTAL values across Melbourne.
- The highest levels of PTAL (6a/6b) were recorded in the CBD, extending beyond the Hoddle Grid and particularly in the east to Richmond.
- Inner suburbs (where trams operate) record moderate PTAL values (PTAL 4 along railway corridors and 3 beyond that). Higher PTAL values extend south to St Kilda and Brighton.
- All railway lines exhibit higher PTAL values, with the base PTAL value at stations being 1b. Longer station spacings are noticeably visible in the outer suburbs (Dandenong to Pakenham and Cranbourne, for instance).
- Middle suburbs record a base PTAL of 1b, whilst in the outer suburbs, this is 1a.
- A limited number of suburban centres record significantly higher PTAL values than their surroundings. Box Hill and Footscray are key examples, with Dandenong, Oakleigh, Sunshine and Moonee Ponds trailing behind. There are also a small number of non-rail station location accessibility hotspots (e.g., Monash University, Doncaster, Northland).
- Some linear 'patches' of higher PTAL (1b against a backdrop of 1a) exist in the outer eastern suburbs, representing major SmartBus corridors (e.g., Springvale Rd).
- There are large pockets of areas with no population or public transport service (represented in white). Some are protected parklands whilst others (e.g., in the western suburbs and the southeast between railway lines) are genuine infill opportunities. Development patterns follow a 'linear sprawl' pattern along railway lines.

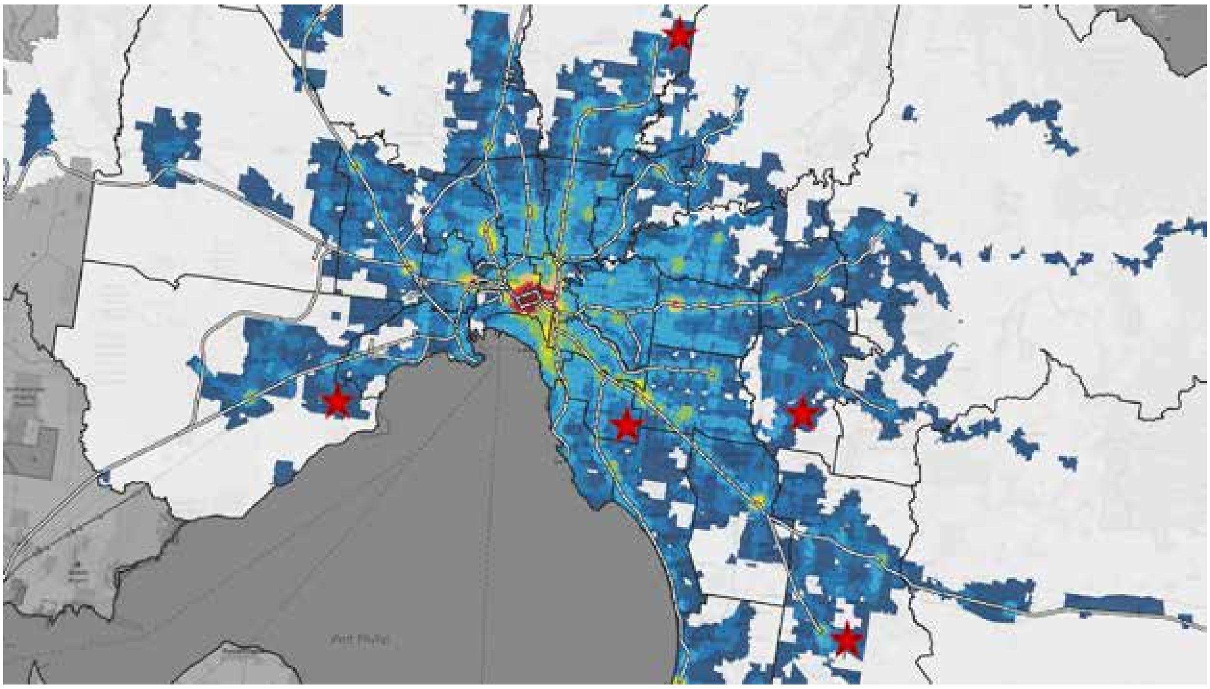


Figure 13: Accessibility analysis of metropolitan Melbourne, showing the five case studies selected for in-depth study

Sensitivity analysis: Temporal variability

The proceeding commentary (and Figure 13) showcased PTAL values in the weekday AM peak, representing a best-case view in terms of public transport accessibility. The same mapping exercise has also been undertaken at other time periods, including the weekday PM peak and weekday inter-peak (measured at 12 noon), as well as at various times of day on Saturdays and Sundays. More rigorous sensitivity analysis to study temporal variability can offer a more holistic view of public transport accessibility. This is particularly important for all-day travel and emerging patterns of work under COVID-19. Frequent networks and high levels of connectivity throughout the day allow people to rely more on public transport systems.

Figure 14 presents a comparison of PTAL values between the AM peak and inter-peak on weekdays. Figure 15 compares the weekday AM peak base with the inter-peak on a Saturday. Several patterns emerge from these comparisons:

- The extent of PTAL decline appears largest in East Melbourne, Richmond, Collingwood and Abbotsford. Further investigation shows that these communities surround Hoodle St, where SmartBus services to Manningham (Doncaster Area Rapid Transit) operate. These commuter express peak-first buses serve a journey-to-work market and exhibit a higher peak-to-base ratio than other services.
- The CBD does not record a PTAL decline, most likely because the weekday AM peak base level of service far exceeds the requirements for Level 6b (the criteria for which is also being met during non-peak times).
- PTAL reductions are less evident in the northern suburbs (Cities of Moreland and Darebin) than in other cardinal directions (especially the northeast, east and southeast). This may be because there is less temporal variability in bus service levels. Often, many bus services feature a standard level of 'policy' frequency without any peak uplift in service levels. The case studies (Chapter 5) reveal that this varies by route and community.

- Some mesh blocks even exhibit a PTAL increase in non-peak times and weekends. Cobblebank (east of Melton) and Caroline Springs, as well as Lysterfield (in the City of Knox and a case study location), are key examples of this surprising phenomenon.

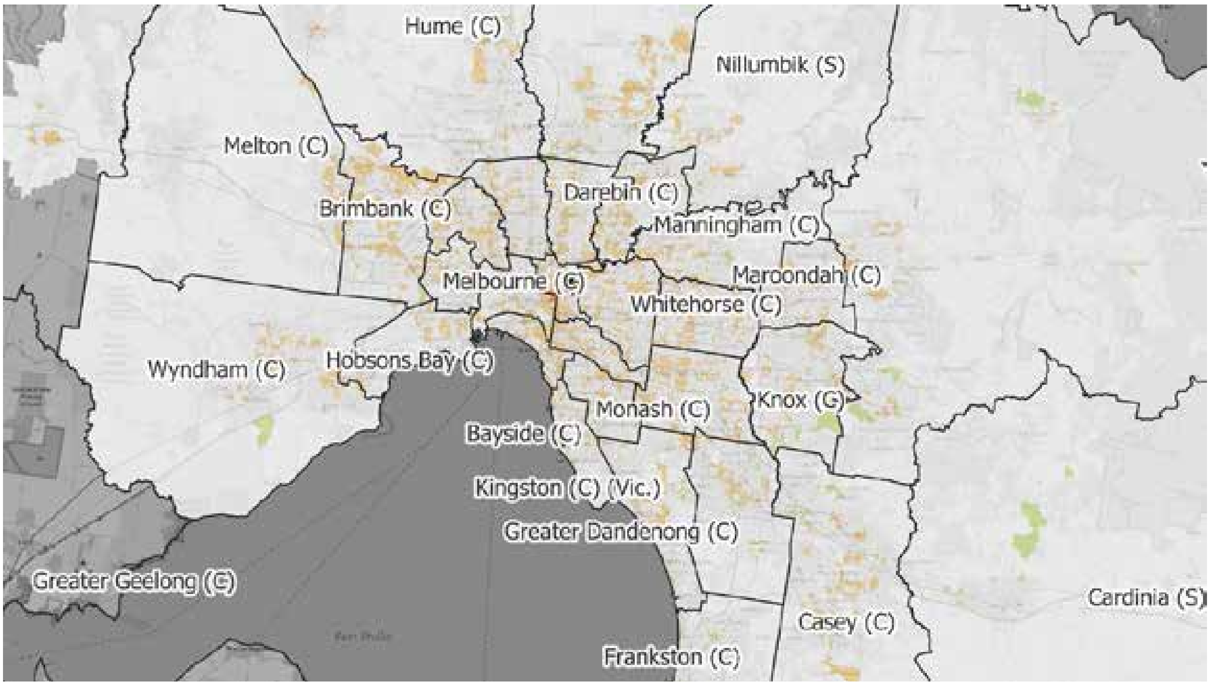


Figure 14: Base (weekday AM peak), compared with weekday inter-peak (orange=>PTAL reduction; green=>PTAL increase)

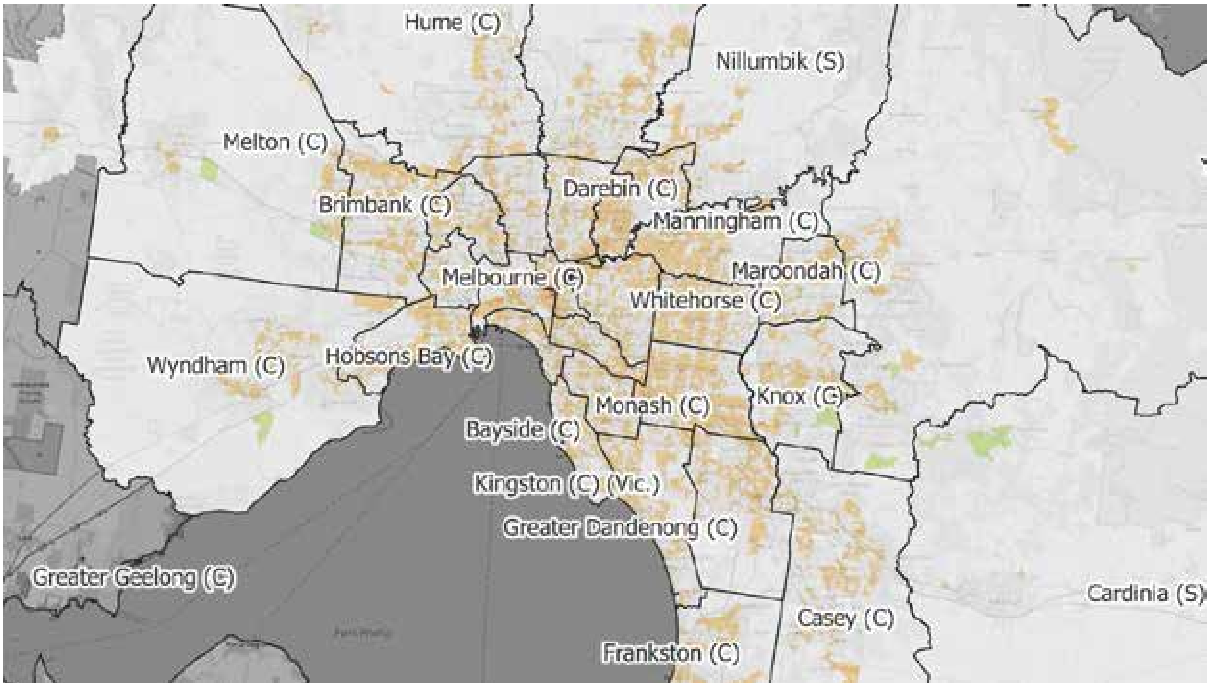


Figure 15: Base (weekday AM peak), compared with Saturday inter-peak (orange=>PTAL reduction; green=>PTAL increase)

Selecting case studies for in-depth investigation

The public transport accessibility patterns established through PTAL scores were used to select case study sites which warrant further in-depth analysis. The results reveal that any number of suburbs/communities can be appropriate candidates since the majority of middle and outer suburb locations can be characterised as exhibiting low PTAL values (1a/1b). The first/last mile is a pervasive issue that exhibits itself in any location far from the frequent network of railway lines, trunk bus services or from a major suburban centre/hub.

To assist case study site selection, an average PTAL index was determined for each suburb. Population data from the ABS was also overlayed to calculate the number of people within different PTAL values (density data supports subsequent discussion in Chapter 5). This ranking of accessibility, and overlayed with the population dimension, was used to inform as part of a multi-criteria method to select the case studies.

The selected locations are displayed in Figure 13 and Table 7. They capture variability in use cases, eras of development, local transport operators and local government areas, with each cardinal direction represented. Further details on these case studies in terms of geographic and public transport services characteristics are presented in Table 10.

Table 7: Rationale for case study selection

Case study	Location	Notable characteristics
Point Cook	Western suburb	• Planned community home to a large multicultural and ethnic population • Relatively higher socioeconomic status (skilled migrants) than in the surrounding, established suburbs • Serviced by a new railway station Williams Landing (located some distance away) • Community groups have introduced transport initiatives (e.g., WYNBUS) to serve local needs
Doreen	Outer north	• Serviced by a new railway extension to Mernda (the station is located some distance away) • Extremely recent growth with middle-class residents
Rowville	Outer east	• Well established post-war community • Highly politically sensitive; promised new railway line for several decades • Well known to have a poor fixed-route bus service • Home to an innovative demand-responsive transport offering (TeleBus/FlexiRide)
Cranbourne East	Outer south-east	• Commuter belt suburb (many young families) • Experiencing rapid growth with continual new developments coming online) • New railway station (Clyde) and railway extension proposed
Bentleigh East	Middle south-east	• Pre-war community; extremely well established • Some gentrification occurring • High levels of bus service and coverage in a gridded neighbourhood • The closest area to central Melbourne with the lowest PTAL value and is entirely dependent on bus services (no trams nor trains)

Chapter 5 presents a discussion on the PTAL results of each case study with reference to local bus networks and their service levels. Relevant findings from a station access survey presented in the following sections are also incorporated.

4.3. Station access survey

Whilst PTAL presents a view on access to public transport of different service levels, it is not able to capture accessibility beyond the first/last mile. Whether the public transport service is actually *useful* (in terms of taking people where they want to go), and the onward service experience is not captured. This includes variables such as the speed or utility of the service, crowding, safety, interchange design, as well as experienced levels of service reliability and punctuality. The PTAL approach is only as valid as the factors considered in the criterion, and this deductive, supply-based, top-down approach can only address the *what* without necessarily understanding the *why*. The addition of an inductive, bottom-up, demand-driven approach to studying customer behaviour and preferences can further add value and complement what was found in the desktop analytics approach.

Design and rationale

Having identified first/last mile connectivity as a major challenge in Melbourne, it is incumbent to complement this finding with the lived first/last mile experiences of Melburnians. The best way to capture qualitative data (understanding *why*) is by means of a survey, though the reality is that such a data collection methodology is costly and labour intensive. The decision was made to target the survey at train customers in a subset of case study sites, namely Williams Landing (capturing Point Cook residents) and Cranbourne (for Cranbourne East). An intercept survey is devised so as to capture station access/egress mode choice. The key outcome is to understand the drivers and motivators for people who travel to and from the station by private car, public transport (bus) and TNC services (such as ridesharing). Specific questions delve into the detail of first/last mile challenges in accessing the bus as a feeder mode.

A deliberate decision was made to focus on existing train customers so as to enable a manual intercept data collection strategy. Whilst a broader survey facilitated by online distribution can capture travel via all modes (including the majority who use the private car *only*), this was a trade-off between data quality, cost and the depth of questioning possible. As identified in Chapter 2, MaaS must have as its backbone public transport (in this case, rail) and has the greatest potential amongst people who are multimodal, either within a single trip or across a period of time (encompassing households who share cars between family members or already have multiple cars).

Expected survey outcomes

The project's focus on using MaaS to solve first/last mile challenges also motivated the choice to survey existing train users. The aim is to understand the reasons for how these train users access the station. What can entice car drivers to consider alternatives? What proportion are driving themselves and how many are receiving lifts, and from who? What are the characteristics of bus users, and what proportion are captive and choice riders? Is access to feeder bus stops an issue, and to what extent is feeder bus service levels a facilitator or constraint to their use? What entices users to consider TNC services like ridehailing, and is this a once-off or everyday choice? What is the willingness to consider active modes, and are present assumptions around the station access shed correct?

One benefit of the sampling focus on existing train users is that it ignores a large number of 'ideological' car users who may have less propensity to consider shared mode travel options. However, this may also miss a segment of 'forced' car-only users who may prefer to use train were it available through a more integrated MaaS package with included first/last mile travel. Residents who use TNC services only in a point-to-point context would also be missed. This is a limitation and exists as a potential for future study.

The survey instrument

The survey questions were designed around respondents' station access/egress trips, mode choice rationale, and the conditions under which they might consider a mode shift. A focus on understanding attitudes and behaviours enabled a confirmation of the first/last mile access challenge established in the accessibility analysis, coupled with hands-on experiences, an understanding of how personal/demographic factors might affect choice, and a consideration of 'soft' factors which were not captured in the quantitative treatment of service levels.

Likert-scale questions were avoided so as to reduce any need for respondents to make assumptions. To avoid hypothetical bias, the survey refrained from asking what users would do in hypothetical situations but instead sought to assess their current travel behaviour (the focus on revealed, over stated preferences). The survey crew asked open-ended questions and classified these on the spot within a set of mutually exclusive (but not collectively exhaustive, with an open-ended "Other" also provided) multiple check box response options. An extensive pilot process with domain experts ensured that the questions, responses, wording and length were appropriate.

Figure 16 presents the structure of the survey instrument and the number of questions within each component. The four branches capture mode-specific insights for drivers, passengers, bus and active mode users to the two railway stations. Questions were designed to be suitable to capture both access and egress data. Appendix A7 provides details of the full questionnaire, including questions and multiple-choice selections in each of the four branches.

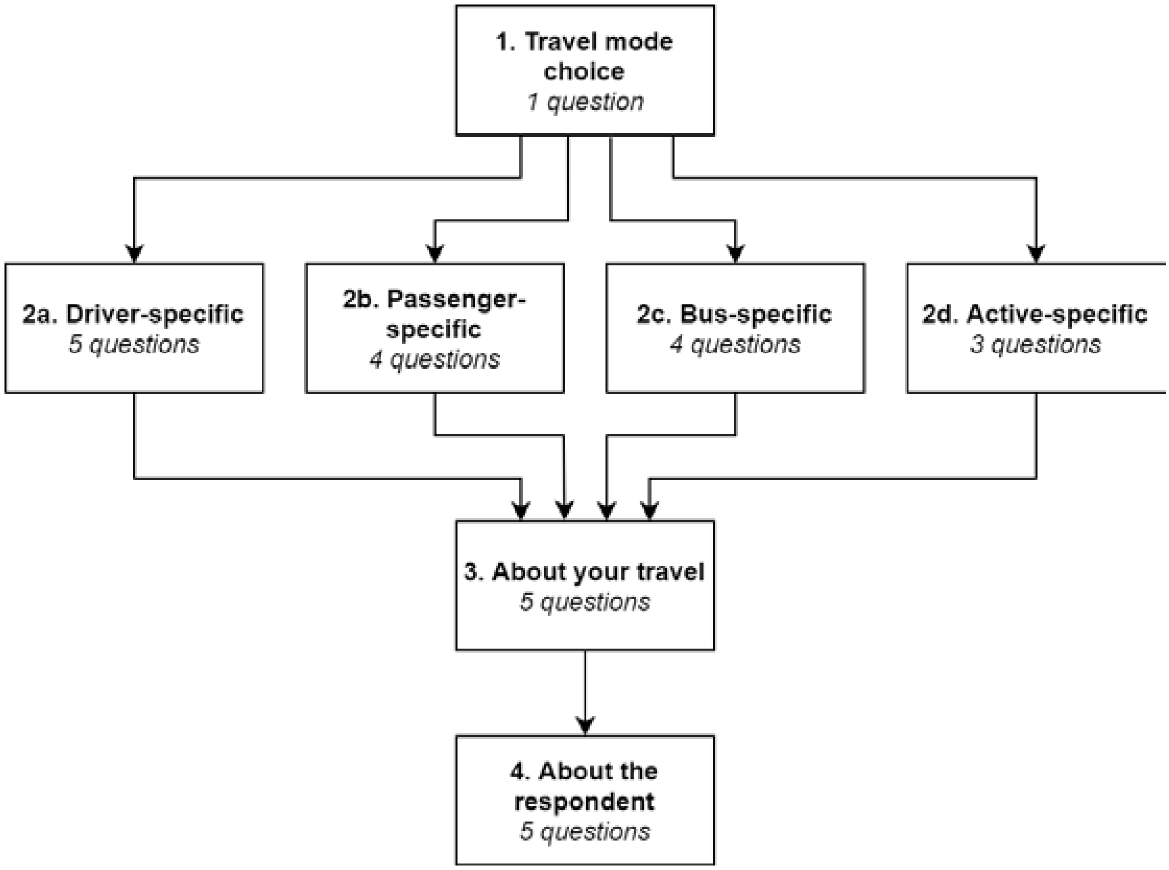


Figure 16: Structure of the station intercept survey

Survey administration

A team of professional survey staff were engaged to administer the survey. The team was equipped with hi-vis jackets and iPads to undertake the computer-assisted personal interviews. Data collection was undertaken in the weekday AM and PM peaks at Williams Landing and Cranbourne interchanges on select days in the months of May and June 2021. From the outset, the decision was made to not survey school children and youth under 18 years of age.

Care was taken to prevent sampling and self-selection bias (though the intercept approach usually oversamples more frequent users). Some people may be more approachable or more willing to engage and share. The survey staff found that customers waiting for buses (in the egress direction) tend to be more willing to engage, as well as in access scenarios where there was a longer lead time before a train’s scheduled departure.

A major challenge was the impact of uncertainty associated with COVID-19 and intermittent lockdowns. This affected both the sample of customers able to be surveyed, the makeup of this sample, as well as some level of trepidation amongst respondents’ willingness to engage with the survey staff. These challenges were managed as best as possible and are constraints that should guide data interpretation.

4.4. Access mode choice

The station access survey results were collected and analysed, focusing on understanding station access mode, the characteristics of this first/last mile travel, the rationale for mode choice, and propensity for mode shift. Descriptive statistics of the sample (n=132) are provided in Appendix A8. This section presents an overview of last-mile mode choice, linking to trip characteristics, whilst Section 4.5 examines some of the preferences and attitudes towards access modes (particularly bus) in greater detail.

It is well established that station access mode is highly correlated with station location (Figure 17). As an example, there is a higher propensity for the use of the car as one travels further from the CBD. Similarly, the propensity to walk substantially decreases as Zone 2 stations are likely to service a larger geographic area and an urban form that is less conducive to walking. Interestingly, the use of the bus also increases in Zone 2. This may reflect the unique spatial circumstances of Zone 1 and 2 (overlap) stations and the fact that Zone 1 stations also offer the opportunity for customers to connect by tram.

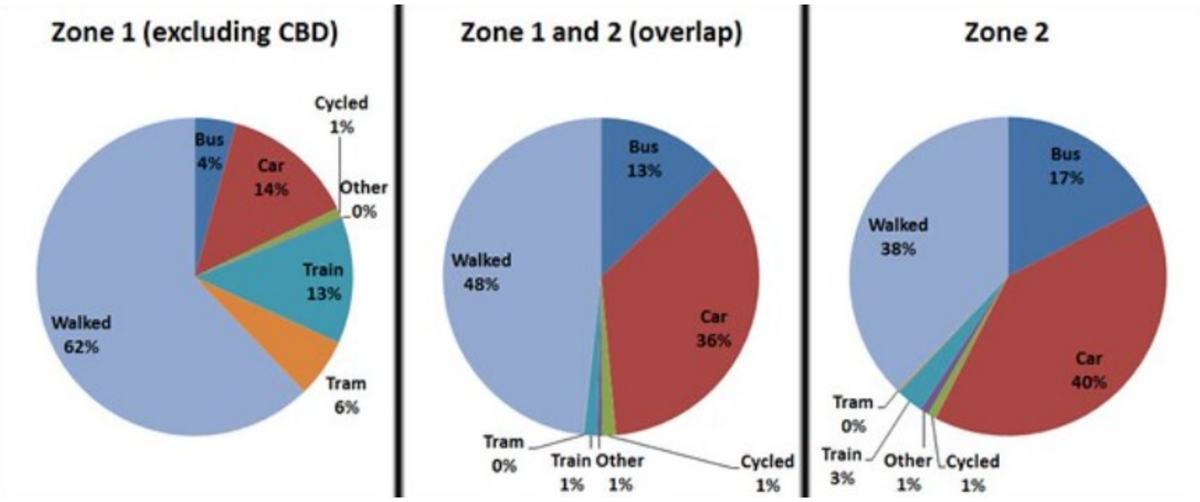


Figure 17: Station access/egress modes at Zone 1, Zone 2 and Zone 1/2 (overlap) stations provided by PTV in 2015 (Bowen, 2015)

This data offers a point of comparison for the representativeness of our survey dataset's station access/egress mode composition (Figure 18). As evident, 56% of respondents travelled the last mile by car. This consisted of:

- 36% of respondents who drove their own car (the other 20% were passengers in a driven vehicle)
- 18% were dropped off, in which case the car in which they travelled continued on another trip, presumably back home or to another destination (a trip chain)
- 12% walked from a parked car, meaning the driver of the vehicle also likely accessed the station

This overall 56% of drivers is slightly higher than the average Zone 2 dataset (40%) and probably reflects ongoing COVID uncertainty and a preference for personalised travel options, as well as the demand-inducing effects of reduced parking utilisation during a pandemic and the associated stresses involved with finding a parking space.

The use of the bus is also higher (24% of surveyed respondents) whilst walking is underrepresented at the locations of interest, given they are public transport hubs and potentially also reflecting the sampling methodology (including the ease of surveying people waiting for the bus). Very few people cycled to the station or used new mobility modes (such as Uber). These are consistent with the overall trends exhibited in Figure 17.

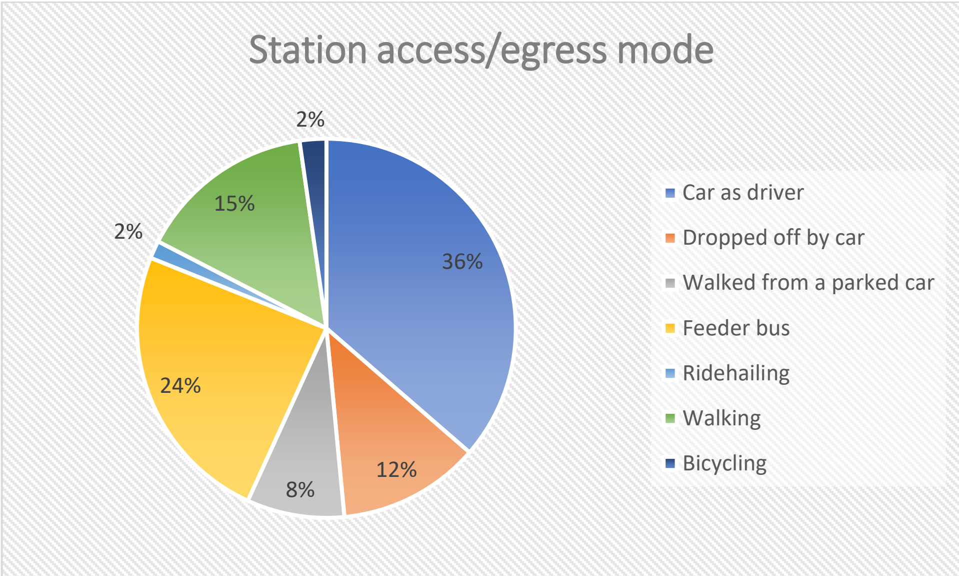


Figure 18: Station access/egress modes identified by surveyed customers at Williams Landing and Cranbourne stations (results combined)

Travel characteristics by mode

It is also useful to investigate in a descriptive sense whether patterns emerge in terms of last-mile journey length, total journey length, and travel purpose conditioning the choice of the first/last mile mode.

Figure 19 shows the distribution of first/last mile trip lengths by mode, showing:

- 6-10 min journey lengths being the most prominent across all access modes
- Walking and cycling being more likely to record longer travel time trips (this may reflect distances where total travel time is comparable to travel by other modes)
- Bus users recording the greatest proportion of trips less than 5 min long

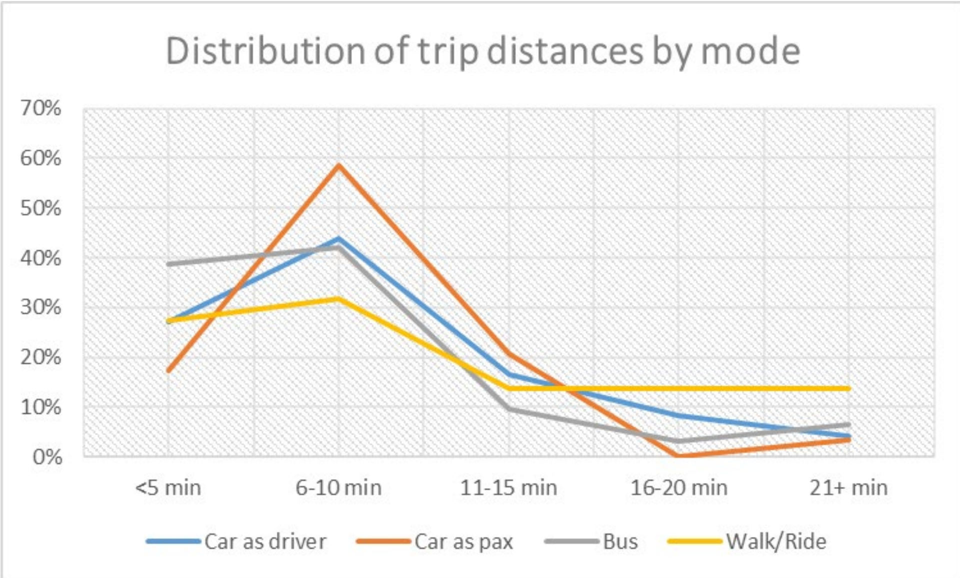


Figure 19: Station access/egress trip distances indicated by surveyed customers at Williams Landing and Cranbourne stations

Figure 20 shows station-specific differences exhibited in the journey length of the trunk mode of respondents (usually train):

- The peak was at 21-30 min journey lengths for Williams Landing respondents (consistent for travel to the CBD)
- An almost bimodal pattern was exhibited for Cranbourne customers. There is a peak at 20 min or less for short-distance travel to Dandenong and the surrounding region, plus a longer distance of 51+ min for travel to the CBD and surrounds (such as South Yarra and Richmond).

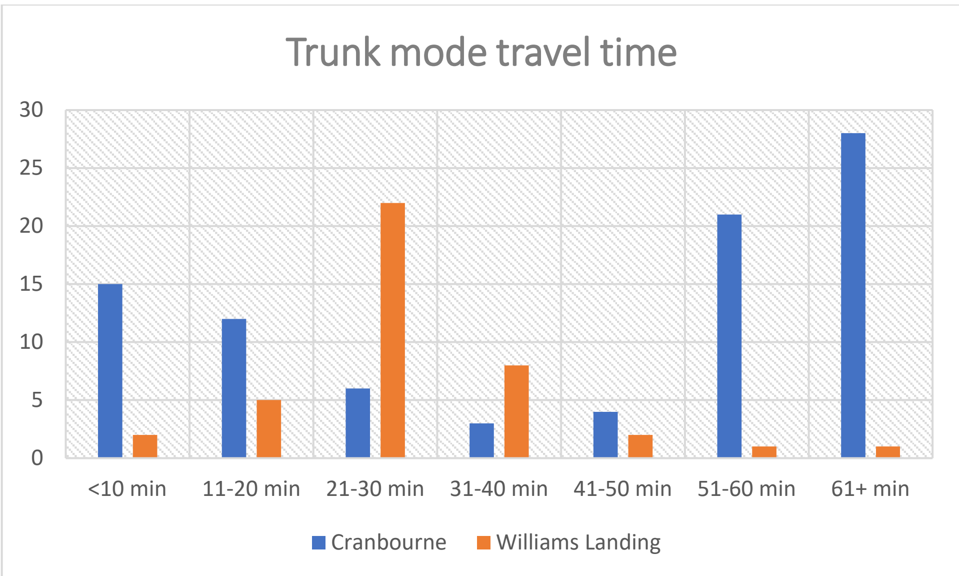


Figure 20: Train (trunk) travel lengths indicated by surveyed customers at Williams Landing and Cranbourne stations

It is worth considering whether the length of the trunk trip might be correlated with respondents' access mode choice:

- Last-mile car (as driver) users are most likely to take longer train rides (50+ min)
- Last-mile bus users are more likely to take a train trip of length 11-20 min

This shows an element of travel time budgeting in play. Specifically, respondents who travel longer distances (which are most likely to be for full-time work) may be more time-sensitive in the first/last mile, and so they choose to drive. Note that there may be some self-selection at work; those who travel further may undertake white-collar jobs and hence have higher disposable incomes for vehicle ownership. More investigation is necessary on these possible links.

Figure 21 shows the frequency of respondents undertaking the surveyed trip. In total, 44% of respondents travelled 4-5 days, with 34% making 2-3 trips per week (possibly as an artefact of remote work). A high proportion of people (19%) indicated that they were travelling for one day only—it is unclear whether these infrequent travellers are making one-off (casual) trips, including as a first-timer, or are simply repeating trips at lower frequencies. No discernible last-mile modal differences were noticeable in terms of the link with travel frequency.

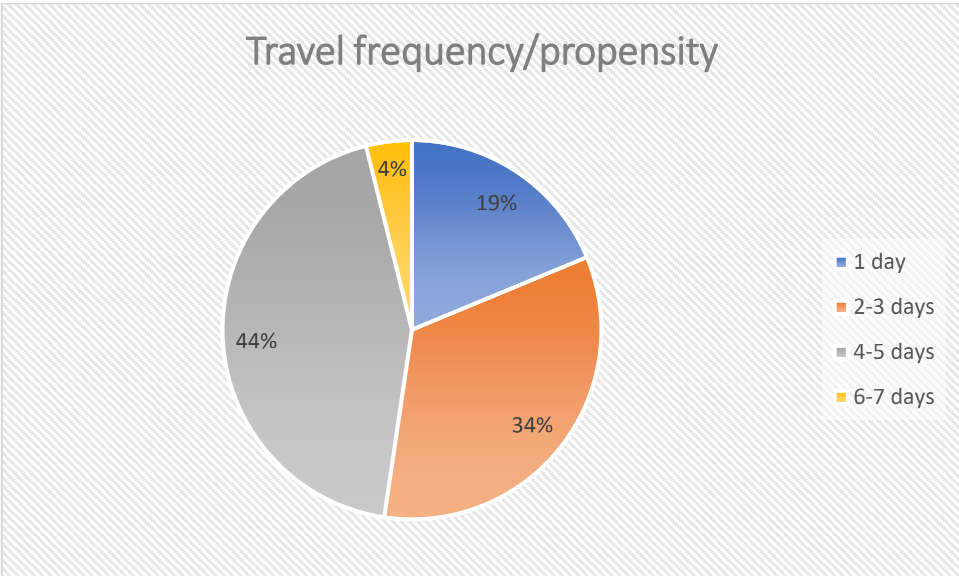


Figure 21: Frequency of travel amongst surveyed respondents

Figure 22 shows the breakdown of travel purposes indicated by surveyed respondents. The vast majority of travel was for work (78%), with a diversity of other use cases also represented. There were clear mode-specific differences in last-mile mode choice:

- For full-time work, some form of car use (car as passenger or driver) dominated (61%)
- For part-time work, all modes of travel were equally likely to be used
- For education, the majority indicated use of the bus (40%), followed by being dropped off by car (27%)
- For most recreational train travel, access was by car (as the driver)

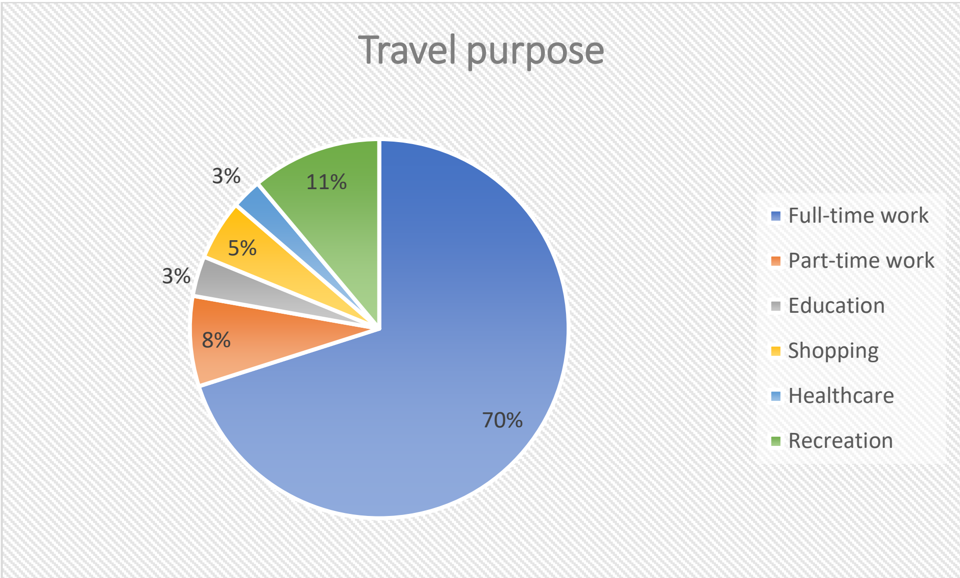


Figure 22: Travel purpose indicated by surveyed customers at Williams Landing and Cranbourne stations

4.5. Bus and non-bus user characteristics and preferences

Key components of the rich dataset are investigated based on the study outcomes/objectives, particularly to study the attitudes and preferences around last-mile mode choice. Specifically, there is a desire to understand:

- Why do existing last-mile bus users (24%) choose to ride the bus?
- Why do existing last-mile car users (56%) not choose an alternative mode like the bus?
- How could last-mile car users be enticed to switch to the bus or other new mobility modes?
- The current role and potential of new mobility modes like ridehailing, carsharing, microtransit and micromobility

Whilst the first three aims are able to be analysed in this section, only 2% of respondents used shared modes (such as Uber), so it was not possible to investigate this class of services.

The captive bus audience

Capture bus users are defined as those with no private vehicle alternative, such as not owning or having access to a car and/or not being in possession of a driving licence. The captive bus market accounted for 69% of the bus users surveyed (a proportion similar in both Williams Landing and Cranbourne). Table 8 displays the characteristics of captive bus riders, who are more likely to be female, younger, and hail from culturally/linguistically diverse communities. This is also true for all last-mile bus users who were likely to be more diverse than the general sample of all respondents surveyed.

Table 8: Characteristics of captive bus users, as compared to all bus users and all surveyed respondents

Finding	Amongst captive bus users	Amongst all bus users	Amongst all respondents
More likely to be female	59% female; 41% male	56% female; 44% male	51% female; 49% male
More likely to be younger	61% under 35; 39% over 35	56% under 35; 44% over 35	55% under 35; 45% over 35
More likely to hail from culturally/linguistically diverse communities [14]	77% non-white; 23% Caucasian	69% non-white; 31% Caucasian	55% non-white; 45% Caucasian

Bus user experiences

Amongst the reasons indicated by *choice* users of the bus (31% of all bus users), cost savings and convenience (mainly linked to the provision of parking) came to the fore. Cost-savings accounted for 20% of all bus user preferences in Cranbourne, whilst bus users in Williams Landing did not describe convenience as a motivation for using the bus.

It is worth investigating convenience as a major factor in network design, a service experience variable MaaS may be able to support. It is known that the median distance people walk from their home to a bus stop (in Melbourne) is 390 metres [15], but interest remains in the distribution of walk lengths and the factors which might vary this propensity to walk. Case studies in Chapter 5 reveal significant variations in potential walk distances (required) amongst different communities.

The surveyed bus users did not identify major reliability issues around bus on-time running, with 58% waiting 5 minutes or less and 32% waiting 6-10 minutes for their bus to arrive. This corresponds with strict adherence to anticipating expected timetabled departures rather than arriving randomly at stops. The proportion of respondents waiting longer times was substantially higher for the egress trip, as expected.

A major source of interest is to compare bus user preferences and the preferences of the bus amongst non-users (i.e., car users). This can help to ascertain whether there are instances of perceptions not reflecting the reality of lived experiences, as well as whether self-selection might have a role in the bus only serving those for which the bus is convenient.

Barriers to bus use: Investigating car user preferences for bus

Last-mile car users were asked whether they have considered as well as the reasons for why they have not decided to take the bus. Around 50% of car drivers have never considered the bus. This compared with 28% of car passengers who have never considered the bus. Amongst the surveyed car passengers, around 30% of these were, in fact, regular bus users who have either missed their bus or were getting a lift on this occasion for other reasons.

[14] Note Cranbourne East and Point Cook are both heavily multicultural communities. According to the 2016 ABS census, 45% of Cranbourne East and 52% of Point Cook residents were born outside Australia.
[15] Finding by Bus Association Victoria in partnership with Victoria Walks.

The barriers to bus use amongst car users are presented in Figure 23. This is divided into car drivers/passengers and the two surveyed sites Cranbourne and Williams Landing. The most common reasons for not choosing the bus were:

- The bus stop is too far from home—particularly in Cranbourne and especially amongst car drivers
- Inconvenient timetables/schedules—this was much larger amongst car passengers (many of whom have used the bus), as well those at William Landing station
- Wait times/reliability were also cited as barriers to bus use (although this was not exhibited amongst existing bus users)
- 92% of car users indicated that they did not need to trip chain (e.g., undertake a school pick up or drop off as part of their drive to the station)—this dispels the myth that trip chaining is a major reason for people's choice in using the car

The results confirm some element of the perceived inconvenience of the bus exceeding its actual disutility. Better communications and the ability to educate the broader public and leverage technology to enhance customer experience could assist. Self-selection may also be at play in that those who use the bus do so because the bus service (routes, stops and operating times) is convenient to them. The bus must therefore be useful to more people to encourage their use.

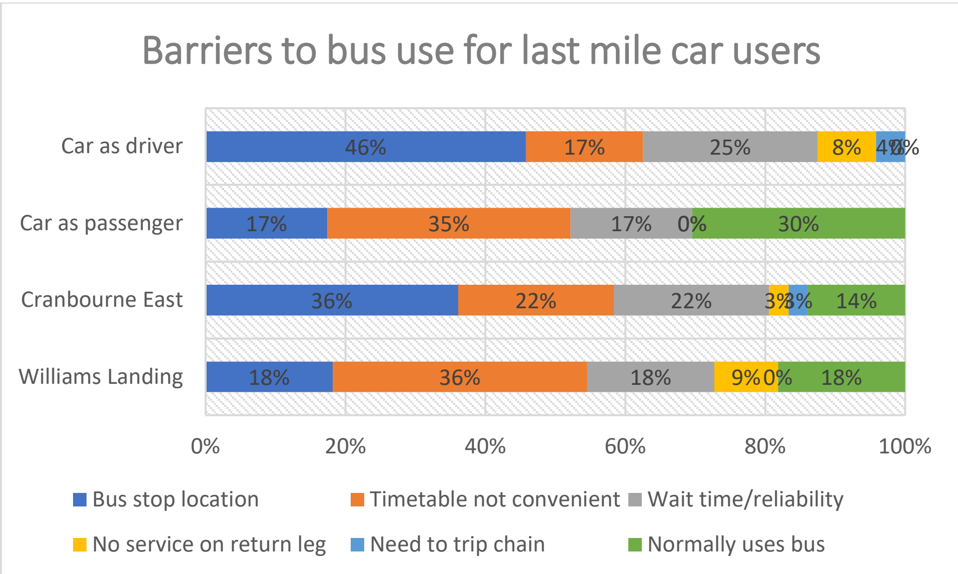


Figure 23: Reasons for not using the bus amongst car users, stratified by driver/passenger status and case study

Contingency modes amongst last-mile car users

The survey asked last-mile car users how they would travel were their car not available (Figure 24). Amongst car drivers, they were equally likely to choose the bus, get a lift, take a taxi/Uber or walk instead. This shows a high degree of flexibility and availability of alternative options, including the willingness to pay for more expensive taxi/ridehailing services. This shows the opportunity to provide new mobility modes of similar convenience but at a lower cost.

The car passengers group, however, were more constrained in their options. This group of respondents were most likely to be driven by a spouse (40%), followed by a friend or housemate (21%). Some were also driven by a parent, sibling or their children.

Recall that a large subset of car passengers were occasional bus users. As such, the bus was the first port-of-call, accounting for more than 50% of their indicated contingent mode choice were their lift not available. This group was also more likely to walk instead of catching a taxi/Uber, showing they were likely to be more price-conscious/sensitive.

There were also some station-specific influencers. Cranbourne residents were more likely to use the bus were their car unavailable. Point Cook residents were more likely to get a lift or take a taxi/Uber. This might reflect higher socioeconomic status in Point Cook and larger household sizes (and thereby the availability of cars/licenced drivers).

Very few respondents indicated that they would not travel at all or not travel to the train station were their access to the car not available.

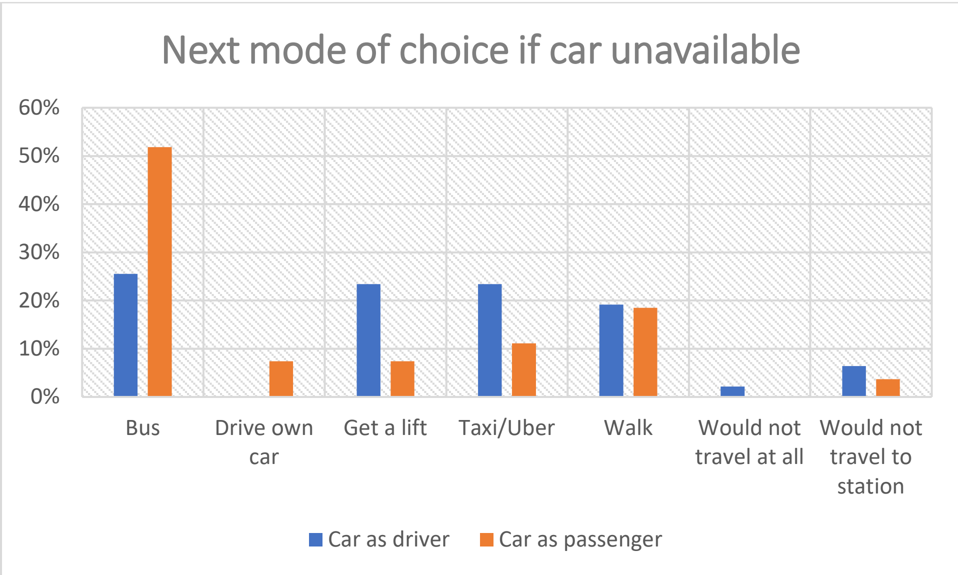


Figure 24: How car users would travel were their car/lift not available

Cluster-analysis investigating last-mile bus use

The preceding descriptive investigation was complemented by a clustering methodology to investigate systematically the patterns which emerge (explicitly relating to last-mile bus use). Based on survey data, a cluster analysis (more details in Appendix A9) was performed to categorise travellers entering or exiting the two train stations (Cranbourne and Williams Landing). The cluster analysis was able to group individuals with similar attributes and examine multiple attributes simultaneously. Here, the cluster analysis is intended to examine what types of people are more likely to take buses as a station access/egress mode.

Respondents in the survey data were clustered into six categories based on an "Elbow Test" for k-means clustering. It should be noted that the sample size is small (n=132), but some patterns do emerge.

The overall bus usage is low. Only 32 out of the 132 sampled individuals use a bus to travel to and from a train station. The highest percentage of bus usage (8/15) came from a group that are high-frequency travellers (travelling more than 4 days a week) (12/15), predominantly female (10/15), and Middle Eastern ethnicity (8/15, the highest of all six groups).

The group with the lowest bus usage (3/32) exhibited a high percentage of school trips (11/32). Finally, a group comprised of younger (aged 19-35) (19/21), high-travel frequency (20/21) Asians (21/21) with work-related trips (18/21) also exhibited above-average bus usage (7/21).

5. Case studies in focus

5.1. Overview

Building on findings from the accessibility modelling and station access surveys, this chapter takes a deep dive into the five selected case studies to investigate network structures, public transport accessibility, first/last miles challenges, and opportunities for service improvement. Each section provides a description of the case study geography, overview of service offerings, unique characteristics/use cases, and practical recommendations to the network and schemes to enhance coverage and connectivity. The solutioning focuses on improving access, including how new mobility modes may complement a reformed fixed-route network, and importantly identifying how a package of improvements facilitated through a MaaS platform may be delivered for the benefit of these communities.

As an overview, it is useful to compare service levels in both qualitative and quantitative terms across the case study areas. Table 9 presents a summary of how service characteristics vary across these five case study locations. Determinations are based on inspection, and it is the relative differences between locations that are of interest.

- **Coverage** specifies to what extent the bus network services the case study area (closely linked to accessibility levels). Bentleigh East is best covered with the shortest bus access distances, whilst large accessibility gaps plague Cranbourne East.
- **Directness** determines network legibility, as well as vehicle speeds and route lengths. Bus routes which ply major arterials (e.g., in Cranbourne East) are more direct than services that meander within suburbs (such as in Rowville).
- **Legibility** refers to the network and schedule complexity of the bus services. Some routes have predictable schedules and service spans, whilst others (e.g., in Rowville) can be overly complex, with many variants, including short works and head offs. Some services only operate on particular days and at particular times.
- **Peak frequency** describes the extent to which service levels are lifted in peak periods compared to the base (or inter-peak). Point Cook, Doreen and Bentleigh East all enjoy increased peak services, whilst in Rowville and Cranbourne East, there is little increase from the base service level.
- **All-day frequency** compares the relative frequency maintained across the inter-peak across different case study sites. Cranbourne East and Bentleigh East enjoy the highest all-day service levels (many routes operate at 20-minute headways throughout the day).
- **Service span** captures the span of operating hours. Point Cook is the only case study site with extended service hours into midnight on Friday and Saturday evenings (excluding public holidays). Rowville's services rarely extend past 6 PM.
- **Weekend** covers the level of service relative to a weekday in each case study location. Cranbourne East has the highest relative service level with service frequencies no different from services on a weekday.

Please refer to Appendix A10 for detailed summaries of individual routes and service levels (and gremlins) for each case study area.

Table 9: Overview of service levels across the five case study locations (based on author's assessment)

	Point Cook	Cranbourne East	Doreen	Rowville [16]	Bentleigh East
Coverage	✔✔	✔	✔✔	✔✔	✔✔✔✔✔
Directness	✔✔✔	✔✔✔✔	✔✔	✔	✔✔
Legibility	✔✔✔	✔✔✔	✔✔	✔	✔✔
Peak frequency	✔✔✔	✔✔	✔✔✔	✔	✔✔✔
All-day frequency	✔✔	✔✔✔✔	✔✔	✔	✔✔✔✔
Service span	✔✔✔	✔✔	✔✔	✔	✔✔
Weekend	✔✔	✔✔✔	✔	✔	✔✔

Table 10 complements Table 9 by presenting a summary of actual public transport physical service characteristics at each case study location. Note that population measures are based on the most recent census data (2016). Cranbourne East and Doreen underwent the most significant developments during the past half-decade, so the population measures for these two case studies are likely to be significantly underestimated.

Service characteristics are compared based on a standard unit of geography—their defined built-up areas (these are illustrated within the accessibility maps in the remainder of the chapter). Major findings include:

- **Service intensity** is highest in Cranbourne East, showing the greatest concentration of services within limited route corridors (more concentrated than even Bentleigh East). On the other hand, Rowville exhibits the least concentration (note that demand-responsive service kilometres are not captured here).
- **Network density** is highest in Bentleigh East and lowest in Cranbourne East, showing significant service coverage gaps in the latter. Rowville exceeds the coverage performance in Doreen and Point Cook, but services are scattered amongst a larger land area (and so poor service frequency could likely be a major source of complaint).
- **Service density** is highest at Bentleigh East. Cranbourne East is the lowest, meaning that despite high service intensity, the aggregate quantum of service kilometres is still low relative to the land area being serviced.
- **Bus stop density** is significantly higher in Bentleigh East than in all other case study sites. Cranbourne East has only 20% of the number of bus stops per unit area compared with Bentleigh East, showing considerable disparities in potential service coverage.
- **Average stop spacing** varies significantly between case study locations. The shortest stop distances were in Bentleigh East, whilst the longest were in Cranbourne East. Stop spacing is a trade-off between service coverage and vehicle speed.
- **Bus mode share** varies considerably, being highest at Bentleigh East. Point Cook performs well for its location, whilst the bus mode share in Rowville is extremely low (both supported by anecdotal evidence). Cranbourne East and Doreen bus mode shares are likely underrepresented due to dated population and modal split data.

[16] Excludes the demand responsive (FlexiRide) component

Table 10: Service levels at each case study site (note that land area is based on the contiguous built-up area within each case study location)

	Population density	**Service intensity**	**Network density**	**Service density**	**Bus stop density**	**Average stop spacing**	**Bus mode share**
	Population per [built up] sqkm	*Service km per route km*	*Route km per sqkm*	*Service km per sqkm*	*Bus stops per sqkm*	*Metres per stop*	*2016 census*
Bentleigh East	3,155.9	33.7	6.5	219.9	16.7	274.4	3.44%
Cranbourne East	1,082.6	34.1	2.0	69.7	3.1	502.2	2.15%
Doreen	1,667.6	31.9	4.0	126.4	7.5	467.6	0.75%
Point Cook	2,495.9	29.2	3.1	91.2	5.8	392.6	3.24%
Rowville [17]	2,366.8	22.2	5.5	122.3	9.3	428.5	1.37%

It is clear from this overview that there is enormous variability in service levels across the case study locations. Bentleigh East was rightly identified as a benchmark with a high level of service as compared to outer suburbs and metropolitan fringe locations. Different design values brought into network planning are also evident, with many network coverage attributes characterised by Bentleigh East and Cranbourne East sitting on extreme ends of the spectrum. Cranbourne East's prioritisation on directness, high frequency, limited corridors, and high service speeds (meaning fewer stops) is not necessarily negative (under the right balance), although the station access surveys did show major issues in access to these bus stops.

A more detailed investigation into each case study can identify nuances and whether current service levels are appropriate, and if MaaS and new mobility modes can be harnessed to address accessibility gaps.

5.2. Point Cook

Point Cook is a diverse, multicultural, middle-class community approximately 22 km southwest of Melbourne's CBD. Point Cook grew since the turn of the century and exhibited a modern interpretation of the 'Garden city character' that is pre-defined and controlled (Tewari and Beynon, 2018)—similar to the other new estate developments of Cranbourne East and Doreen. Residents can connect to Werribee Line trains at Williams Landing station, which opened in 2013. Williams Landing is being grown into a major regional centre, but much of the surrounding land around the station remains vacant at this stage. One of the major transport bottlenecks is the M1 Princes Fwy which lies at grade, with only several bridge crossings available for vehicles and pedestrians. All crossings are heavily congested and, in particular, the not-yet upgraded Point Cook Rd, which provides access to the older communities of Seabrook and Altona Meadows, as well as the existing stations of Laverton and Aircraft.

[17] Excludes the demand responsive (FlexiRide) component

Key transport characteristics of the Point Cook case study are provided in Table 11.

Table 11: Key characteristics of the Point Cook case study

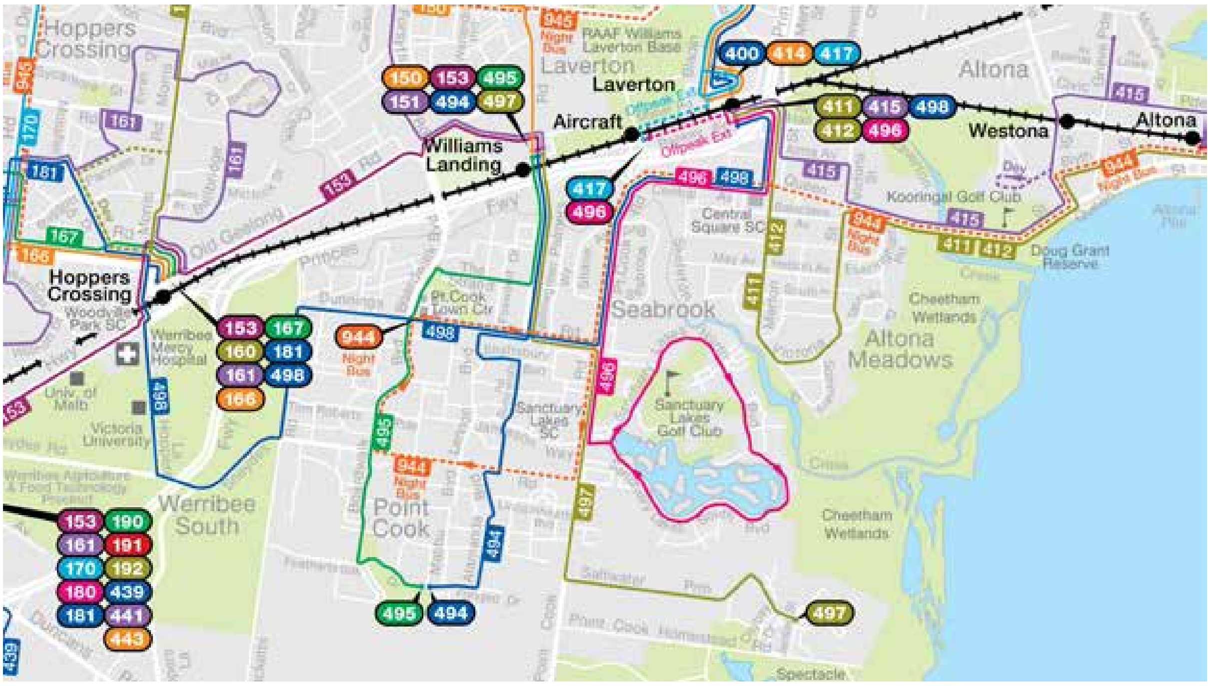
	Key Characteristics
Williams Landing station	• Newly constructed in 2013, featuring high quality waiting amenities, a bus interchange and commuter car park • Lengthy walking distances within the interchange precinct • Limited walkable catchment around the station (land banked by developers—temporarily used as private, overflow car parks)
Bus network	• Recently reformed in June 2015 • Above-average route productivity (>50 pax/shr) across Wyndham Shire • Coverage gaps in the western perimeter of Point Cook (1km+ from the nearest bus stop)
Bus service	• High peak service on R/495 (6 bph in the PM peak) • Fri/Sat late-night services on R/494 and R/495 (rare in Melbourne)—soon to be 24HR services • R/494 and R/495 operate on an interlined basis (effectively a loop)—not evident on customer-facing material, including applications • R/498 and R/181 are also interlined to provide a one-seat service to Werribee (also not communicated) • There is a lack of service coordination at the Point Cook Town Centre
Road/urban structure	• Heavy congestion for inbound services to station hubs: Palmers Rd for Williams Landing and Point Cook Rd for Laverton

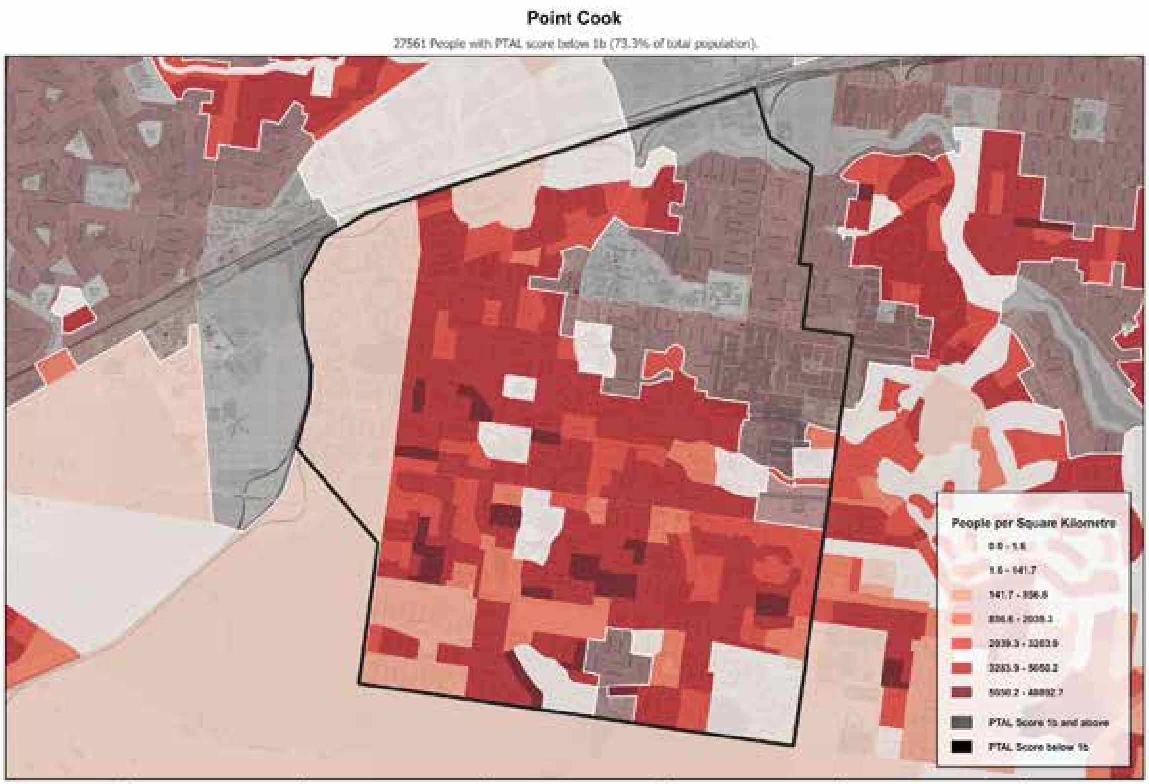
Figure 25 presents the current bus network structure and illustrates the population density distribution in Point Cook, overlayed by two levels (high, PTAL>1b; or low, PTAL<1b). Ideally, higher PTAL values (the cross-hatching) should be found in areas with higher population densities (darker reds). Some key patterns emerge from these mapping outputs:

- High public transport accessibility in the northern end of the suburb where there is higher route density
- Higher PTAL along Palmers Rd with a confluence of routes, as well as at the Point Cook Town Centre and Dunnings Rd
- Where PTAL is >1b, bus services are no more than 400 m away
- Black spots exist in the south-west of the suburb (where new residents have moved in since the last census date)—this shows a need to respond to new growth and to provide better coverage
- There are pockets of density scattered throughout the suburb—this may be due to larger household sizes or MAUP [18] (patterns that emerge due to the method of mesh block aggregation)

[18] The modifiable areal unit problem (MAUP) describes how the spatial unit definition (e.g., blocks of houses or groups of people) can affect the outcomes of variables in aggregation.

To address the poorer public transport accessibility on the western and southern sides of the suburb, the Point Cook Action Group operated the (since discontinued) demand-responsive WYNBUS to supplement the fixed-route bus network. The service provided enhanced coverage and a convenient link to Hoppers Crossing railway station.





Area (Square Km)	Population	Population below 1b	% of Population below 1b	People/Square Km
15.08	37581	27561	73.3	2492.7

Figure 25: Point Cook bus network and first/mile accessibility (in the cordoned case study area)

Some examples of service reform opportunities to enhance accessibility, as well as what a MaaS solution should seek to address, are provided. This commentary is based on physical service requirements with an added spatial dimension to suggest points of interchange that a MaaS offering should seek to support. More general requirements for developing and implementing MaaS that is case study agnostic is provided in Chapter 6. The opportunities in Point Cook include:

- Provision of an **east-west frequent bus link** on Sneydes Rd, intersecting with Route 495 at Featherbrook Shopping Centre and Route 494 at Soho Village. This service can continue to Hoppers Crossing Station, Werribee Plaza and Werribee station on the west and Laverton station to the east. Together with Route 498, this provides a gridded network and, with sufficient frequency, four points of **coordinated transfer** for convenient travel and connections not only to Williams Landing but also to points of interest such as Werribee Plaza.
- The addition of a **north-south bus service** in the west of the suburb. From Williams Landing, this route can serve Boardwalk Blvd, Hacketts Rd and Featherbrook Dr. This also supports the future growth of the suburb westward.
- The key challenge of severe traffic congestion on the limited number of 'bottlenecked' routes across Princes Fwy can be an opportunity to improve the travel time relativity between bus and private car (the key to public transport success). Enhancing **bus right-of-way** on key corridors (including Point Cook Dr) via bus lanes and queue jumps can enable the bus to be a more time competitive travel option and support mode shift.
- The provision of demand-responsive transport or subsidised ridehailing is not recommended within the case study areas (although this could be suitable for the adjoining Sanctuary Lakes, presented serviced by Route 496).
- Point Cook is ideal for the deployment of a **dockless micromobility** offering. On-road cycleways exist on key arterial roads, which could be supported by speed limit reductions (e.g., reducing from 70 km/h to 60 km/h) and implementing traffic calming measures. The deployment zone can be contained within an area of sufficient density and a diverse mix of travel demand and use cases. The combination of local/casual trips to the number of local centres (including Point Cook and Sanctuary Lakes Shopping Centre), together with first/last mile trips to Williams Landing station and the scatter of recreational and educational facilities within the suburb, can help balance (often heavily peaked) travel directions and demand.

INNOVATION IN FOCUS: WYNBUS

The Point Cook Action Group has long identified a host of transport issues in the Point Cook community, particularly relating to the poor coverage of bus services. Part of the issue is that much of the community has narrow roads with buses unable to enter, as well as the limited operational agility of bus routes which once set are difficult to change easily. The Action Group has tried petitions and lobbying and found a "passing of the buck" between local and state governments.

In 2018, the Action Group participated in the Victorian Government's *Pitch A Project* program where any organisation can make an application, with the public choosing (via a poll) which projects they would like to see funded. The Group campaigned vigorous at stations, local shops and community events, and drew community support for small buses to operate which "sweep the interior of the estate". This was supported by a survey which garnered more than 500 respondents. A total of AUD 31,800 was provided for the program, from which WYNBUS was born.

The funding constraint meant that WYNBUS was heavily reliant on a partnerships model, and was only able to deliver the service for an initial 6 week period. CDC Victoria, as the local bus operator and interested in growing route services in the region, contributed 4 Hyundai iMax vehicles as well as drivers. WYNBUS engaged another social enterprise called Local Transit so as to be disability compliant. They also obtained access to a booking platform provided by a local start-up called Xemo. The greatest barrier was the absence of a legal framework to operate their services but in the end (and with the support of the council), WYNBUS was able to navigate a complex legal exercise and officially became a service provider via a custom agreement.

The service design was heavily engrained in community needs, focusing on the western and southern portions of Point Cook. A fixed route service was operated in the AM peak, given that predictability was a heavily desired factor, and to ensure that connections to train services could be guaranteed. During the off-peak, a more bespoke service for the disabled and elderly was provided, including the option to use WhatsApp to arrange pick up and drop off times and locations. WYNBUS routes were designed with traffic conditions in mind, hence the decision to connect with trains at Hoppers Crossing station.

WYNBUS has since concluded its operations, with the Action Group's efforts now focused on deploying a similar service in Tarneit Grove, another recently developed estate not yet served by new bus routes. The Action Group is working with Wyndham Council to unlock underutilised assets, such as community transport and council vehicles. Point Cook Action Group's initiatives showcase value in a social procurement, bottom-up model as well as the risks and legal/regulatory huddles which must be overcome to deliver transport services which are required only due to inadequacies in the formal fixed-route network structure.

5.3. Cranbourne East

The Cranbourne East case study encompasses both Cranbourne East and the rapidly growing Clyde North community on the southeast metropolitan fringe of Melbourne. In the 2019-20 financial year, Cranbourne East was the second-fastest-growing [19] suburb in Australia, welcoming an additional 6,300 residents (ABS, 2021).

Services in Cranbourne East were upgraded as a "Trainlink" service in November 2003, which ran a largely one-way loop through the community and connected with trains at Cranbourne station. A new bus network was implemented in November 2016, which provided additional services. There remained a poor connection to Berwick (in the north), where many education and health services may be found. New Routes 888 and 889, which provide this connection, were offered via an open tender through a 2.5-year temporary contract funded by the Growth Areas Infrastructure Contribution that developers pay. These services began in March 2021.

Delbosc et al. (2015), in a combination of on-board bus surveys and a survey of Selandra Rise residents (covering both bus users and non-bus users), found poor bus service penetration, with Route 798 covering only 20% of the estate's development footprint. An overwhelming 75% of respondents used the bus to travel to Cranbourne shops or the railway station, with 22% continuing on a connecting bus or train service. The main reason for the use of the car was because of a lack of car access, with most specifying that they would get a lift were the bus not available. These findings are consistent with the results of the station access survey undertaken in Chapter 4, which also found a high number of people driving to Cranbourne station and taking onward buses, including Route 798 to Frankston.

Key characteristics of the Cranbourne East case study and its bus network are provided in Table 12.

Table 12: Key characteristics of the Cranbourne East case study

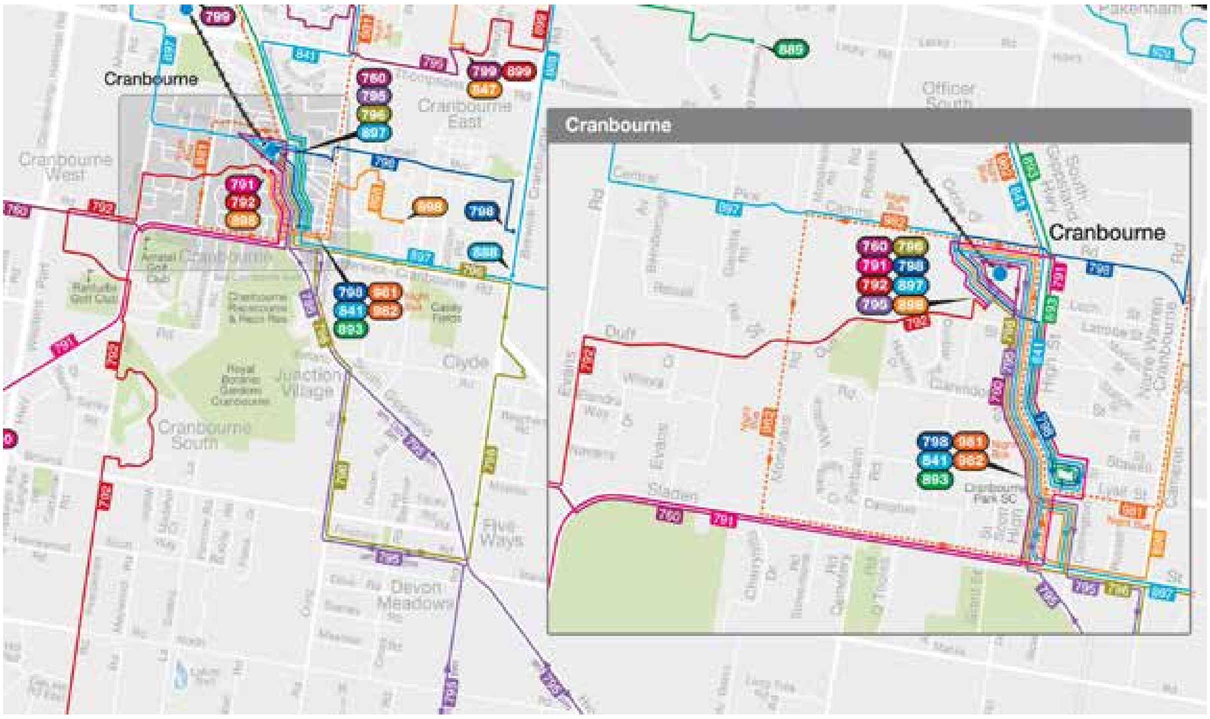
	Key Characteristics
Cranbourne station	• Single entrance on the southeast side—huge deviation required to access western and northern destinations • Large commuter car park on the northside of the station • Limited land use 'activation' within the station precinct—Cranbourne shopping centre is ~1 km south
Bus network	• Heavy consolidation of services on limited trunk corridors • Sparse coverage between routes • Large stop distances (stops at mid-block—suboptimal for resident access) • Clyde North is not serviced (up to 2km from the nearest bus stop), despite bus bays already having been built • Estate south of Berwick-Cranbourne Rd (Casey Fields) not serviced • Poor access to Selandra Rise as a local centre for residents • R/888 and R/897 terminate without an 'anchor', with virtually no connectivity for transfers

[19] The highest growth was in northwest Sydney, in Riverstone-Marsden Park which grew by 8,900 people n 2019-20.

	Key Characteristics
Bus service	• High level of all-day service (except R/788) • R/798 headway erratic in the AM peak, despite average 4 services/hr • Excess running time identified throughout schedules
Road/urban structure	• Sparse trunk arterials (often congested) • Limited connectivity on internal (local) road network structures • Berwick-Cranbourne Rd is a high traffic and high speed corridor with no safe crossings for bus stop access

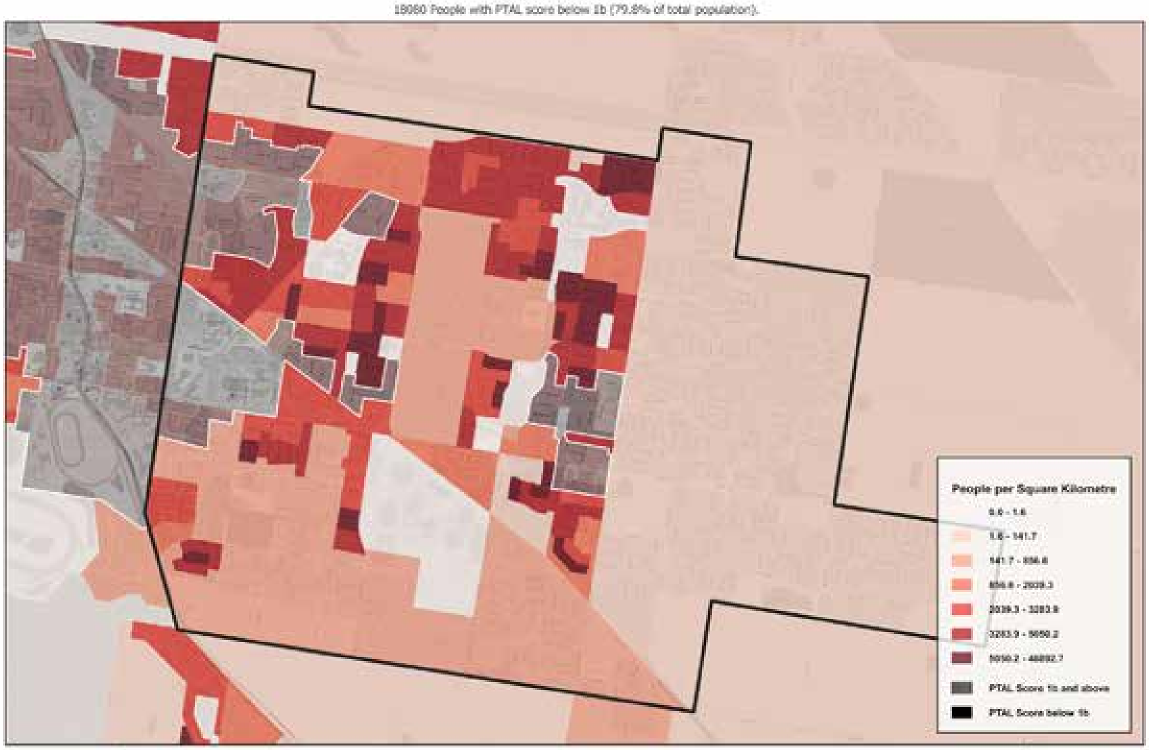
Figure 26 presents the current bus network structure and the accompanying accessibility to these services. Note that the entire development to the east of C407 Berwick-Cranbourne Rd (where Route 888 operates) was developed after the last census date, and so population and accessibility data is not captured/available. Important findings around public transport accessibility patterns in Cranbourne East include:

- Most of Cranbourne East records a low PTAL value
- The exception is to the northwest of the case study where Routes 798 and 898 operate in close proximity and (to the south of this) in the corner where Routes 898 and 897/796 operate (but the land use in this block is industrial).
- No service east of C407 Berwick-Cranbourne Rd (Clyde North), where the nearest bus stops can be 2 km away for residents
- No service south of C407 Berwick-Cranbourne Rd (Casey Fields), where the nearest bus stops can be 1.5 km away for residents
- Higher population densities around Selandra Rise shopping centre
- Section of low-density, large housing blocks (east of Casey Field Blvd) which straddle new developments to the east and west



Cranbourne East

18080 People with PTAL score below 1b (79.8% of total population).



Area (Square Km)	Population	Population below 1b	% of Population below 1b	People/Square Km
19.76	22665	18080	79.8	1147

Figure 26: Cranbourne East bus network and first/mile accessibility

Significant network reform opportunities exist in Cranbourne East to serve public transport deserts and to reduce first/last mile connectivity issues. Specifically, such initiatives could include:

- **Recalibrate the patronage/coverage trade-off** to extend coverage within the scope of existing resources. This could take place by diluting frequency to provide additional routes. Existing routes should feature more stops and ensure existing stop placements are optimal to maximise catchment.
- Examples of route realignments/extensions include:
    - Extend Route 888 into Cranbourne station and the Cranbourne shopping centre so as to provide a strong anchor point and support bi-directional passenger flows through to estate and on to Berwick and Narre Warren (including possible extensions to Fountain Gate Shopping Centre)
    - Extend Route 798 to Clyde North estate
    - Extend Route 898 to Casey Fields estate
- Implement a **branded bus solution** to simplify communication of the service offering between Cranbourne station and the Cranbourne Shopping Centre.
- Undertake **arterial road redesigns** to slow traffic and improve pedestrian crossing opportunities, targeting access to bus stops.
- **Leverage community transport** assets to provide an immediate solution for servicing Clyde North. Integrate the service information (and possibly bookings) within an integrated MaaS offer.
- Consider **shared ridehailing partnerships** within clearly defined zones within the estate.
- Prepare plans to serve the future Cranbourne East and Clyde railway stations, with the proposed reopening of South Gippsland Line.

5.4. Doreen

Doreen is a middle-class community in the outer north of Melbourne, approximately 28 km north of the CBD. The suburb has experienced very recent growth/development, contiguous with the suburbs of Mernda and South Morang. The residential estate (called Laurimar) is said to emphasise "semi-rural" living as an estate design motif. However, block sizes are small and narrow streets constrain bus operations, which connect the suburb to the new Mernda rail extension.

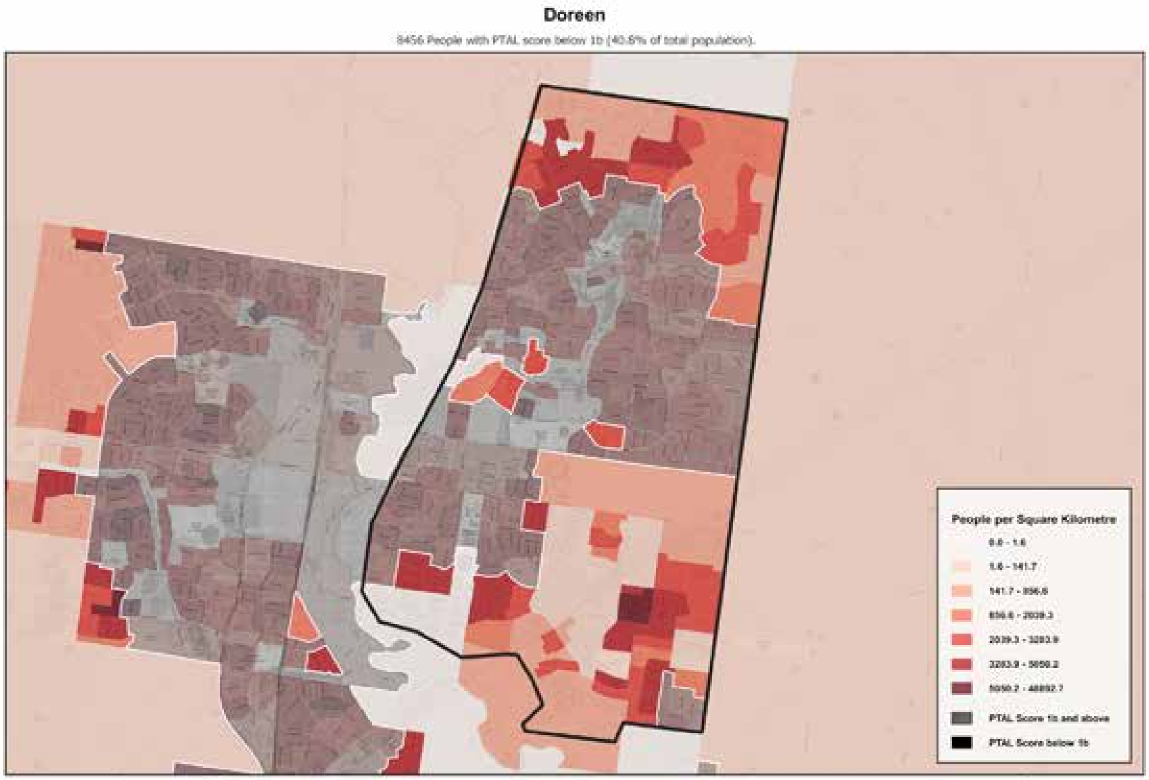
Key public transport and road network characteristics of the Doreen case study are provided in Table 13.

Table 13: Key characteristics of the Doreen case study

	Key Characteristics
Mernda station	• Opened 2018 as an extension to South Morang Line • Elevated, straddling Bridge Inn Rd • Large car park and bus interchange • Town centre located 500 m west • Limited land use 'activation' and walkable catchment
Bus network	• Coverage focused, despite onward routing of R/381 to Diamond Creek station
Bus service	• High peak service on R/389 (4 services/hr) • R/388 loop operates in single direction (anti-clockwise) on weekends (note the different loop designation philosophy to two independent interlined routes which together form a similar loop in Point Cook)
Road/urban structure	• Extremely narrow roads, constraining bus operations • Heavy congestion on Bridge Inn Rd towards Mernda station

Figure 27 presents a snapshot of accessibility within the suburb, showing a reasonable level of public transport accessibility across the majority of the residential estate:

- A generally acceptable PTAL score (>1b) across Doreen, with the Laurimar Town Centre well serviced
- Routes 381 and 388/389 provide adequate coverage but both trade off in terms of route directness
- Where both routes interact, the 400 m access threshold is met adequately
- In the north of the suburb, where only Route 381 is available, a lower PTAL value (<1b) is exhibited
- Areas south of Bridge Inn Rd record lower service levels, except near Mernda station
- The areas immediately surrounding Mernda station are low density, but this is likely reflective of old data



Area (Square Km)	Population	Population below 1b	% of Population below 1b	People/Square Km
11.4	20724	8456	40.8	1817.7

Figure 27: Doreen bus network and first/mile accessibility

Whilst the PTAL scoring shows the Doreen bus network performing better than both Point Cook and Cranbourne East in terms of service coverage, some transport reform opportunities exist, including:

- **Audit road infrastructure** on bus routes to support heavy vehicle access. This could include altering the design/placement of traffic calming measures, the design of roundabouts, and extending no parking/stopping zones. Optimising bus stop location and ensuring the ease of bus manoeuvrability is also important.
- Support the development of a **trunk bus corridor** between the Mernda and Hurstbridge railway lines, as well as access to nearby SmartBus routes. This route should emphasise frequency, speed and directness, and will assist in providing 'gridded' connection opportunities in northeast Melbourne.
- **Leverage community transport assets** to deliver immediate services as the development perimeter of Doreen extends.
- Consider **shared ridehailing partnerships** within clearly defined zones within the estate.
- MaaS can help provide a one-stop information platform for customers using these future new services.

5.5. Rowville

Rowville was established as a subdivision in the outer eastern suburbs during the 1980-90s. This was during a lean fiscal period for the state government, and so only a limited bus service offering was delivered. As a historical anomaly, the area never received a full local bus network to the scale of what is usually expected for a mature suburb. This service backlog has never been properly addressed, but rather the promise of a railway link has been 'dangled' on and off the agenda over several decades (hence the political sensitivity of the area).

One of the compromise developments has been the provision of a demand-responsive service, connecting residents to Ferntree Gully station and SmartBus routes at Stud Park. This was originally launched as the TeleBus and has now been upgraded to become a digitally enabled service known as FlexiRide (key points of difference are provided in Table 14). The TeleBus concept has been successful and shown to generate patronage which exceeds fixed-route services in similar areas with high levels of car ownership (Usher, 1994).

Table 14: FlexiRide as compared with TeleBus and conventional fixed-route bus (Melbourne on Transit, 2020)

Feature	Fixed route bus	TeleBus	FlexiRide
Fixed stop locations	Many	Some	None
Fixed route and stops allows facilities eg bus lanes, shelters and seats?	Yes	Rarely	No
Fixed departure times from main stops	Yes	+/- 5 min	No
Fixed arrival times (eg to connect with trains)?	Yes	Yes (but may be variations)	No
Travel time varies due to deviations?	not applicable	Yes, somewhat	Yes, greatly
Effect on waiting times if patronage rises	Small	Depends if extra passengers request deviations.	Large
Allows spontaneous travel with no notice	Yes	Only at designated stops	No
Need to book trips via phone or app?	No	Only pick up trips requiring deviation	Yes
Bus can deviate to be nearer your house?	No	Yes	Yes
Fare surcharge applies	No	For trips requiring deviation	No
Call centre overheads	No	Yes	Yes but may be less with app
Fixed service km (ie able to reliably budget for)	Yes	Partially	No
Bus runs if no passengers	Yes	Yes	No

The TeleBus was supplemented by Routes 681/682 created in 2002, with a particular aim to improve weekend services. The 'spaghetti' layout of local roads in Rowville makes direct fixed routes that provide reasonable coverage difficult (hence the extremely circuitous routing). Routes 681/682 (and their many variants) continue more or less unchanged even with the advent of FlexiRide.

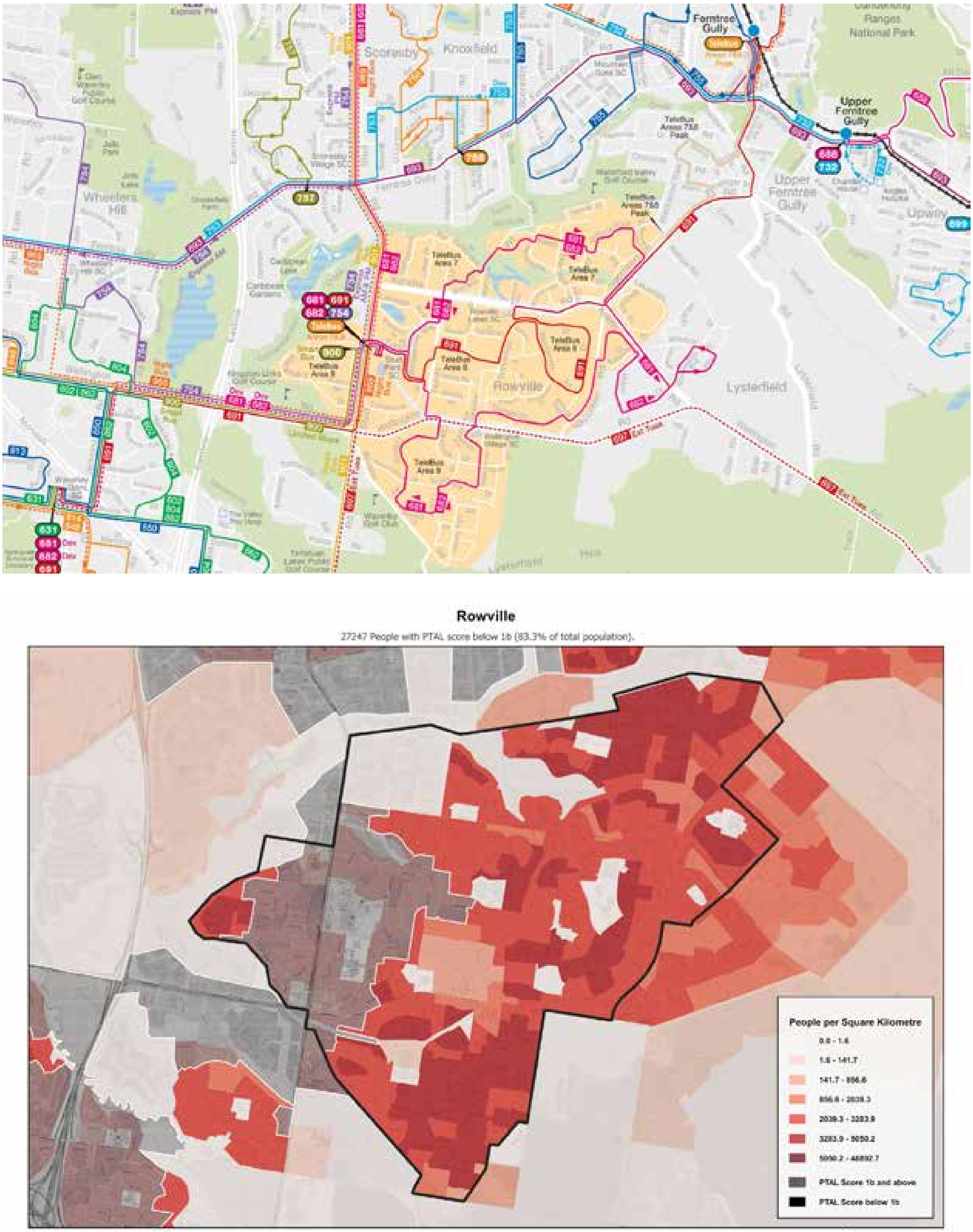
The key transport and land use characteristics of the Rowville case study are presented in Table 15.

Table 15: Key characteristics of the Rowville case study

	Key Characteristics
Ferntree Gully station	• A small local centre (Boronia is significantly larger) • Service frequency is lower, due to a branching at Ringwood
Stud Park centre	• A regional shopping centre but extremely auto-centric • Provides connections to SmartBus R/900 and R/901
Bus network	• FlexiRide provides a demand-responsive service • R/681 and R/682 perform a similar coverage function to FlexiRide • Significant historical legacies on R/681 and R/682, with deviations to Waverley Gardens and Knox City (despite convenient connections on new SmartBus services) • Trunk R/691 runs through the FlexiRide area (likely competing with FlexiRide) • R/691 has indirect portions and a weak westerly terminus (Waverley Gardens, which is now no longer the area's main shopping centre)
Bus service	• Extremely complex variants and stopping patterns on R/681 and R/682 (almost impossible to understand for the customer) • Limited frequencies on R/681 and R/682, focusing on peak direction services (with a limited service span on weekends) • FlexiRide does not operate on weekends
Road/urban structure	• Extreme automobile reliance • Politically sensitive area—promised railway for many decades

The Rowville case study boundaries were defined in accordance with the operating area of TeleBus (this has since expanded to encompass Lysterfield with the FlexiRide revamp). The accessibility mapping in Figure 28 confirms very poor public transport availability. Due to data limitations, the FlexiRide service is not captured within the PTAL scoring. Specific accessibility patterns and findings include:

- Extremely poor PTAL scoring, except surrounding Stud Rd where SmartBus 901 operates
- Population density is in the mid-range for a suburb in its location
- The Lysterfield expansion for FlexiRide is sensible and extends the demand-responsive service to the edge of the built-up area
- Route 691, despite its trunk status, does not provide a strong public transport core for the suburb
- There is an urgent need for network reform and greater service quantity



Area (Square Km)	Population	Population below 1b	% of Population below 1b	People/Square Km
13.62	32722	27247	83.3	2403

Figure 28: Rowville bus network and first/mile accessibility (the

One major issue is that FlexiRide serves a similar coverage function to Routes 681/682, both of which have incredibly complex variants, hours of operation and service patterns. It can also compete with the trunk Route 691. An important lesson from this exercise is that demand-responsive transport should be overlayed on a reformed network rather than one which is compromised so as to ensure maximum complementarity and minimise wasteful competition. Demand-responsive transport is most appropriate where it can replace fixed routes that deviate and double-back on themselves whilst connecting at strong anchor points with frequent service. Rowville is, therefore, a suitable setting for on-demand, but its current implementation severely comprises the success of both the fixed route and demand-responsive networks.

Specific opportunities to improve access and connectivity in Rowville include:

- **Optimise the FlexRide service offering.** Ensure it does not serve (or prices out) customers who can use Route 691 (thus eliminating wasteful competition). Extend operating hours to include evenings and weekends. This also makes better use of the vehicle assets.
- An enhanced FlexiRide service allows **Routes 691/692 to be cancelled**. These customers are now served full time by FlexiRide. Onward travel to destinations like Waverley Gardens and Knox City can be made at Stud Park by SmartBus.
- **Extend SmartBus Route 900** to Ferntree Gully or Boronia (subsuming Route 691). Make this service more direct by removing the Wentworth Ave/Dandelion loop. This provides a strong service core for the area.
- **Integrate FlexiRide and fixed route services within a MaaS platform**. This will assist with optimising connections at all points of interchange, as well as improve customers' journey experiences.

INNOVATION IN FOCUS: TELEBUS/FLEXIRIDE

The TeleBus was established by Croydon Bus Service in 1978 and consisted of four operating zones—Croydon/Lilydale and, later, another around Rowville (Usher, 1994). The service pioneered the use of midibuses which depart and arrive at their termini (train stations), as well as intermediate stops at fixed times, but deviate, on call, to be nearer to passengers' homes. The efficiency of these services is heavily dependent on the skills and knowledge of each driver, who put together the itinerary of each trip. Customers make bookings via telephone, which are communicated from base via an ultra-high frequency two-way radio system. Many TeleBus users were regular and made 'subscription' bookings. Although TeleBus was less productive than most fixed route buses, it did perform better than other flexible bus services in similar locales.

Upgrades to the service have been brewing for several years. The Rowville TeleBus was upgraded with a digital booking/routing platform (using a white label of the Moovit solution) and relaunched in December 2020 with a fleet of new vehicles (the Optare Solo). FlexiRide is fully demand responsive with 100 virtual bus stops in the Rowville and Lysterfield areas, whilst continuing to offer a fixed destination at Stud Park and Ferntree Gully station. Customer surveys and trip feedback showed many converted drivers and former Uber users on the service, and excellent patronage success (having quadrupled from 40 per day under Telebus to more than 160 passengers per day).

Whilst the upgrade of a dated dial-a-ride service is welcome, the new service was implemented without the usual public consultation usually governing network reforms. There was also no change in the existing route service network, leading to wasteful duplication/competition. FlexiRide is officially a trial, and no public information exists on trial length of what will constitute success.

5.6. Bentleigh East

Located 14 km to the southeast of the Melbourne CBD, Bentleigh East is entirely dependent on bus services (no trams nor trains) and emerged in Section 4.2 with an accessibility index on far with outer Melbourne. This is despite an abundance of bus routes and relatively high levels of service coverage—a disparity that warrants further analysis. This case study is used as a point of comparison to compare public transport service levels against the above four case study sites.

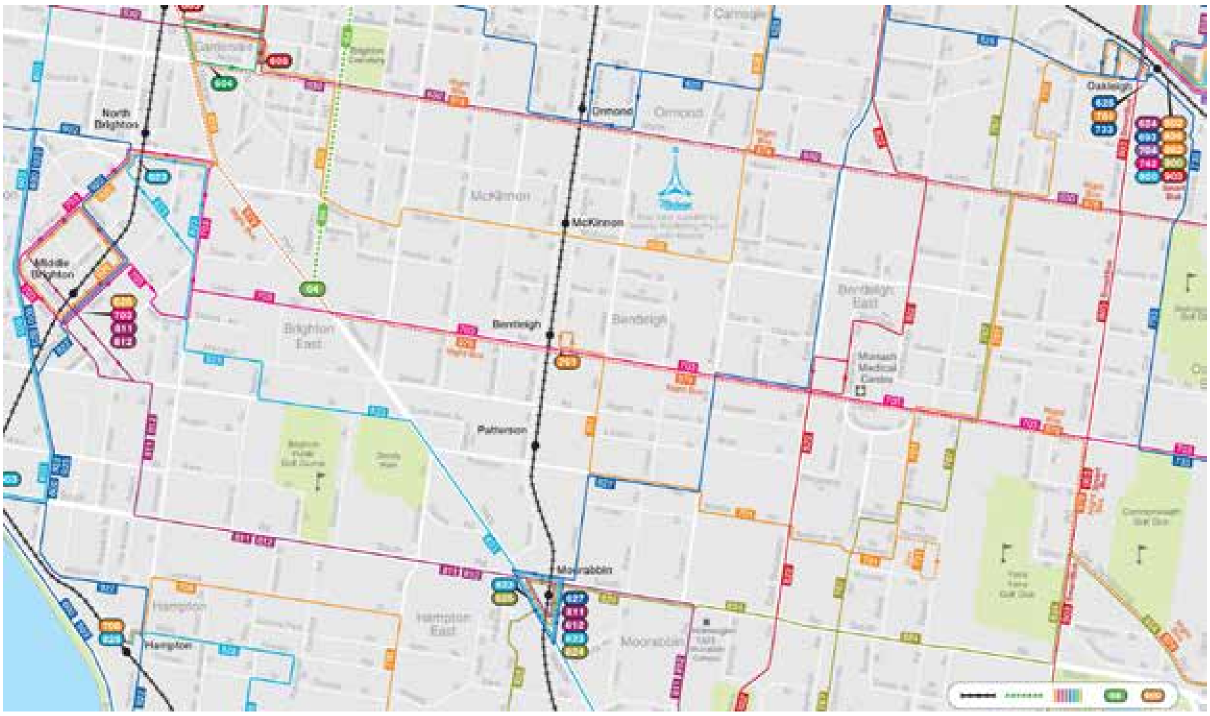
Table 16 summarises the key characteristics of the Bentleigh East case study.

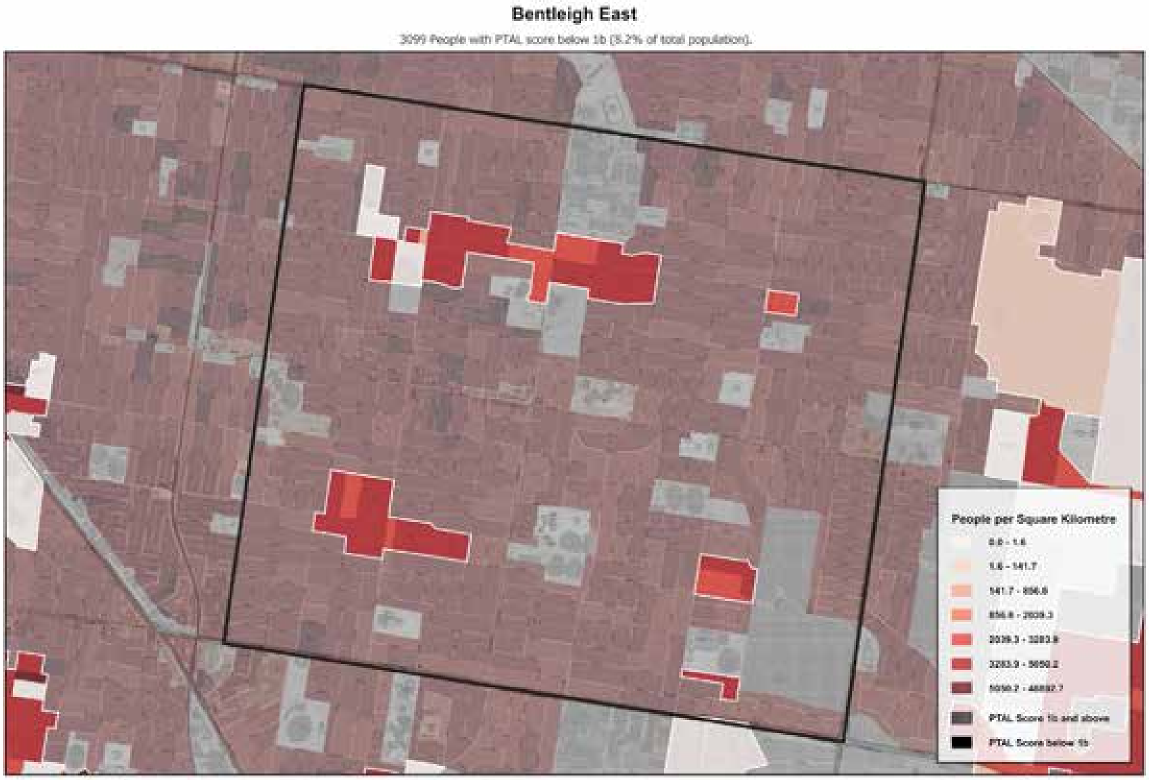
Table 16: Key characteristics of the Bentleigh East case study

	Key Characteristics
Nearby stations	• Major interchanges at Oakleigh and Moorabbin • Connection opportunities at Bentleigh, McKinnon and Ormond (amongst others)
Bus network	• Direct, trunk corridors in the east-west direction • Circuitous routing on north-south routes
Bus service	• The majority of services are trunk or regional
Road/urban structure	• Higher urban density • Greater anywhere-to-anywhere travel

Figure 29 shows the current state of accessibility in the case study area. The mapping of PTAL and population density shows:

- Excellent service coverage, with almost the entirety of the case study area recording PTAL >1b
- Limited pockets of lower service along McKinnon Rd near East Boundary Rd
- Significant pockets of higher density residential near Centre Rd and North to McKinnon Rd





Area (Square Km)	Population	Population below 1b	% of Population below 1b	People/Square Km
11.98	37718	3099	8.2	3149.3

Figure 29: Bentleigh East bus network and first/mile accessibility

Despite high service levels, Bentleigh East can still benefit from minor service modifications as well as the deployment of a MaaS platform. Specifically, these opportunities and benefits include:

- **Consolidate north-south corridors** (e.g., Routes 701 with 767) to offer higher combined frequency. This requires careful co-scheduling but improves overall network legibility and route directness.
- Subsidising ridehailing or microtransit is not recommended given the already high level of public transport service offering.
- Bentleigh East could benefit from a **dockless micromobility scheme**. This can help provide access to local points of interest such as schools, shops and hospitals, as well as the many railway stations surrounding the suburb.
- Successful micromobility requires **road space reallocation** to prioritise low-speed modes. In particular, the present arterial road network is spatially restrictive and not conducive to the use of personal mobility devices.
- A MaaS platform can help integrate the large variety of travel options and modes already available and improve navigation amidst excessive complexity in travel options (i.e., many routings available for the same origin-destination pair). The multitude of retail and other businesses within the precinct can also be an opportunity for the MaaS player to explore **multiservice partnerships and collaborations**.

6. Implementing MaaS in Melbourne

6.1. Review of empirical findings

The preceding two chapters brought together a collection of empirical findings that are both deductive and inductive, as well as covering a combination of the local and global (Melbourne-wide) contexts. The accessibility analysis provided a high-level overview of public transport availability which was supported by in-depth analysis and station access surveys conducted in selected case study areas. Bringing together this evidence base, Table 17 summarises the main findings relating to physical service availability, the integration experience and customers' attitudes/behaviours, particularly pertaining to the first/last mile and multimodal connectivity. These are presented as challenges for which MaaS must seek to resolve.

Table 17: Summarising key findings from Chapters 4 and 5

Key findings	What MaaS must resolve
Highly variable public transport service availability; decreases with distance from CBD and from rail stations	Fix coverage gaps; provide easier access to the frequent public transport network
Bus stop locations and placement are inconsistent and far from home	Provide better access to feed bus stop locations
Timetable flexibility is a barrier to bus use	Better coordinate customer requirements with the transport service offering
Wait time reliability is a barrier to bus use	Provide better real-time customer information
A disconnect between the perceived inconvenience of the bus (amongst non-users) with the reality experienced by bus users	Improve transport service marketing, informational design and communications
Opportunity to encourage public transport use amongst non-frequent car users	Opportunity to package modes together as a behavioural nudge mechanism
Limited TNC-provided new mobility modes on the metropolitan fringe	Encourage more equitable TNC entry to market, with a priority focus on growth areas
An inability for new fixed-route services to meet urban growth demands	Help support more agile transport service provision in new urban developments

6.2. MaaS readiness in Melbourne

Having presented a case for MaaS in Melbourne, it is necessary to consider to what extent Melbourne is prepared (and able) to implement a multimodal MaaS offering.

The **MaaS Maturity Index** developed in Goulding and Kamargianni (2018) is one method to evaluate a city's readiness for MaaS. The index is based on characteristics across five dimensions: (i) transport operators' data sharing and openness; (ii) citizen familiarity and willingness; (iii) policy, regulation and legislation; (iv) information and communications technology infrastructure; and (v) transport services and infrastructure. This schema has been heavily adopted in the European Union and provides a practical 'helicopter' view of MaaS potential.

The MaaS Maturity Index has been adapted and applied in Melbourne as a starting point. The scoring determination for each of the 17 criteria was corroborated with domain experts and presented in full in Appendix A11. Figure 30 summarises the key categories of the index, showing market potential and policy readiness to be particularly poor. In Melbourne, the overall public transport mode share is low and vehicle ownership rate high, factors that may influence MaaS package design, including their scalability and modal mix (e.g., the proportion of public transport compared with car-based TNC modes). Some other constraints include the lack of third-party sales support for public transport tickets and the absence of open application programming interfaces (APIs). These readiness issues are further investigated in this chapter via an in-depth stakeholder engagement exercise conducted with local Melburnian and broader industry players and experts.

Category		Score/100
Overall Score		61.30
Market Potential		53.35
Policy Readiness		40
Data Availability		70
System Integration		68
Travel Behaviour		73.32

Figure 30: MaaS maturity indicators for Melbourne, based on the aggregation of 17 criteria [20]

[20] Graphics supported by the international think tank and consultancy Cities Forum, based on a tool programmed to support capacity building and MaaS adoption in Indian cities.

6.3. Stakeholder ideation

The readiness indicators serve as a motivator and starting point for considering the requirements for enabling MaaS in Melbourne. As presented in Section 2.3, delivering MaaS requires collaboration between a complex set of actors spanning the public and private sectors (across all modes, hard and soft infrastructure). Figure 31 presents the possible assortment of stakeholders that can form part of the broader MaaS ecosystem. At its heart, however, the MaaS broker/aggregator (or provider) brings together demanders and suppliers by enabling cooperation between mode-specific operators (including public transport operators and TNCs) and non-mobility providers (such as digital platforms and third-party payment solutions, shown within the extended enterprise category).

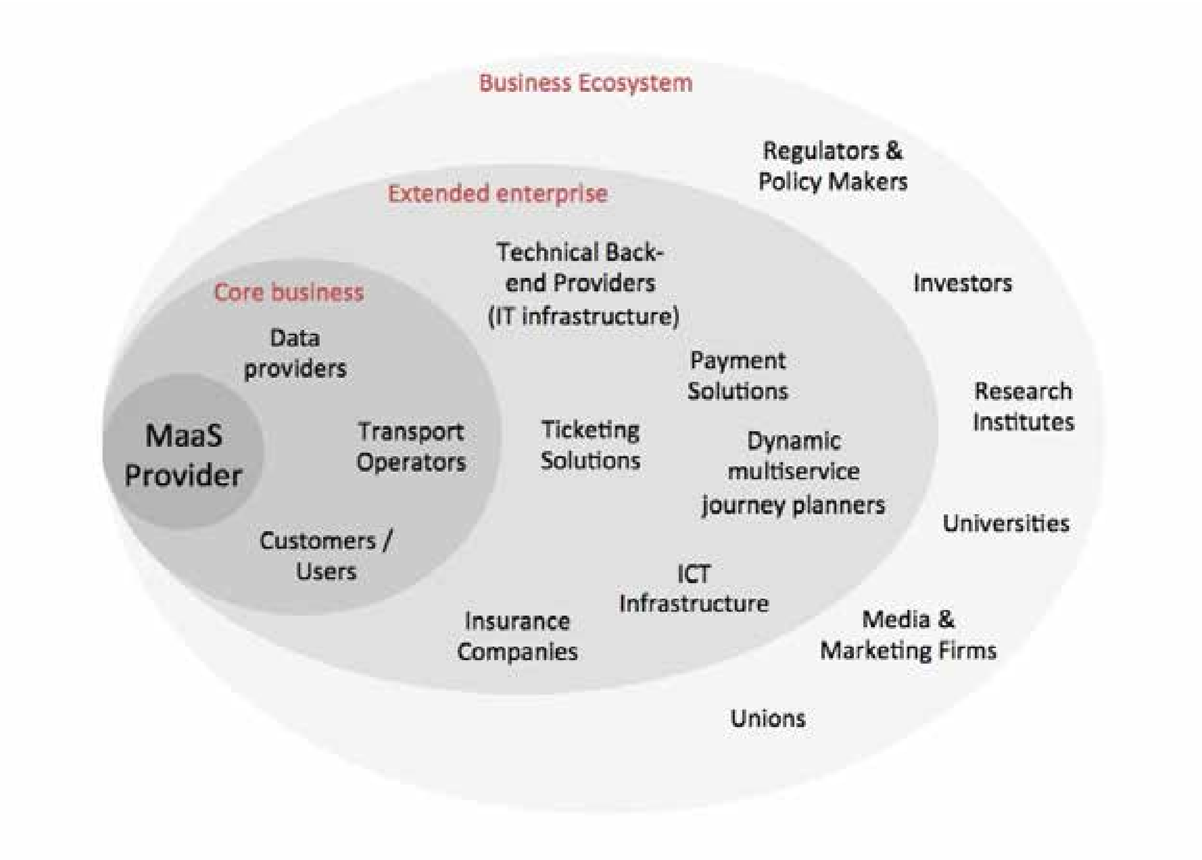


Figure 31: The multifaceted MaaS ecosystem, showing a wide range of actors across the public and private sectors. The role of the MaaS provider (also known as the broker/aggregator) is fundamental in bringing all the necessary components together (Kamargianni and Matyas, 2017: 7)

In this report, the focus of stakeholder ideation is on core business stakeholders, coupled with domain experts who work directly with MaaS enablers to bring a broader perspective on Melbourne-specific implementation challenges. Conversations were held in various formats, including one-on-one interviews, workshops, and in-person site visits (including to the case study locations). A total of 26 organisations are represented (Table 18), including government (state and local), transport operators, technology providers, consultancies, academic institutions and trade associations.

Table 18: Key informants by sector and jurisdiction

Sector	Victorian	Australian/International
Government	Department of Transport	
	City of Casey	
Public transport operators	Metro Trains Melbourne	
	ComfortDelGro	
	Moreland Bus Lines	
	Cranbourne Transit (Pulitano Group)	
Transportation network companies	Lumi Ride	Uber Transit
	WYNBUS	Bird Rides Australia
Technology providers	MaaS Australia	Via Transportation
	Arevo	Moovit
	Placie	Smart Cities Transport
Consultancies	John Usher Associates	cOlab and Associates
	MRCagney	Transit Graphics
		Cities Forum
		FACTUAL
Academic institutions	Monash Institute of Transport Studies (ITS)	Institute of Transport and Logistics Studies (ITLS)
Trade associations	Bus Association Victoria	Intelligent Transport Systems (ITS) Australia

A significant revelation is that the stakeholder ideation process constituted the bridging of two discrete disciplines or schools of thought. On the one hand, the innovation/start-ups crowd often saw technology as an end in itself. These individuals were, at times, quite ideological about the weaknesses of fixed-route public transport and saw digital services as a panacea for solving many of the follies of traditional transport operating models. On the other hand, career public transport professionals brought a very traditional understanding of integration; these individuals focused on coordination and networking planning without giving credence or consideration to the potential of new mobility modes. They brought the view that fixed routes were always the best solution (anything else would be a compromise) and expressed heavy scepticism around the potential or value of new mobility modes. It is clear that individuals in both camps rarely collaborated and remained siloed in their professional work. Building trust and forming a foundation to collaborate is an important first step.

It is necessary to integrate these two strands in considering how MaaS might solve first/last mile challenges. No technology is able to integrate where there are no physical services available to be integrated. Equally so, TNC services democratise what has traditionally been regarded as 'public' and provide smart new ways of bringing together transport demand and service supply (and, in doing so, optimising the use of assets).

Given the challenge in bridging two distinct sectors, Table 19 provides a high-level summary of the major barriers and facilitators in terms of collaboration and participation in a shared MaaS ecosystem. Findings are further explored in the subsequent themed sections—by physical service, digital infrastructure and governance/procurement.

Table 19: Barrier and facilitators to collaboration amongst key stakeholders as part of a MaaS proposition

Mode	Key barriers	Key facilitators
Rail	• Not sufficiently incentivised to consider how people reach stations • Patronage initiative too blunt • More focused on engineering and rolling stock innovations	• Most important trunk mode • Initiatives able to be scaled quickly across the network
Bus	• Seen as "subservient" to the Department • In the domain of delivering kilometres; not appropriately incentivised • Present network highly compromised	• Knows the community and key demands • Excellent operational knowledge • Able to (theoretical) redeploy service at reasonably quick notice
Ridehailing	• Fragmentation amongst service providers (need for multihoming) • Surge pricing not popular amongst customers • Regulatory requirements deemed inequitable and counterproductive for public transport partnerships	• Relatively mature market • New propositions evolving which are less dynamic and able to capture greater efficiencies
Carsharing	• Free-flow carsharing not yet available • Governed by councils, extremely complex to coordinate • Users unlikely to pair with public transport in the same trip (but may use on a weekend as part of a package)	• Extremely popular and growing quickly • Opportunity to reduce car ownership (but still have the convenience of access on demand)
Microtransit	• Confoundment of vehicle size with fixed/flexible route structures • Disparities in how the mode is procured/regulated (where contracted or commercial)	• Easily captures the support of government/political stakeholders • Opportunity to consider new models which straddle existing commercial or contracted frameworks

Mode	Key barriers	Key facilitators
Micromobility	• E-bikes operating in the CBD and inner suburbs only • Poor reputation due to city's prior experiences with bikesharing providers • Limited council areas (3 in metropolitan and 1 in regional) being considered for e-scooter trials • Fragmented regulations across state jurisdictions	• Appetite for right-of-way reallocation to support active mode travel • Victorian government regulatory change for personal mobility devices in line with the National Transport Commission's recommendations • Open desire amongst operators to share data and integrate with other modes (especially as compared with the ridehailing sector)
Technology provider	• Possible fragmentation with bilateral and 'closed' ecosystems forming • Limited government engagement/consistency of support • Government sharing of public transport data feeds and APIs ad hoc and inconsistent	• A plethora of market participants; rapidly growing home-grown and multinational contenders • Significant differences in service philosophies, products, designs and solutions • Many solutions freely provided; most providers desire to diversify their business models

6.4. Physical service requirements

Amidst the excitement of new technologies and the desire to clutch at the low hanging fruit of digital applications is often the failure to address root issues such as service availability and levels of service. Indeed, the MaaS conversation often neglects that any digital platform must have physical services available to be integrated. This reality has been the starting premise of this report and motivated the accessibility modelling showing significant spatial variability in public transport availability across Melbourne. The service availability of new mobility modes also closely align with this pattern.

Any MaaS proposition should ideally be based on an optimal public transport network at its core, with TNC-provided modes linking to this backbone. Buses provide the nearest public transport service to most Melburnians and hence should form the focus for any reform effort (being the most agile in terms of the ability to tweak routes and service levels).

Planning bus networks

A Department of Transport representative described Melbourne's bus network as "a sad story of neglect", based on "incremental nonsense" with a network structure which is a "hopeless bowl of spaghetti". Other stakeholders have described the Department as "not committed to real service planning". Whilst the appropriateness of these exact descriptors may be argued (and there is significant variation in terms of the efficacy of bus networks in different communities), it is clear that there has traditionally been a very limited funding focus on buses (especially relative to trains and trams or roads), and bus patronage and service levels in Melbourne are very low for any internationally comparable city of a similar size. [21]

The stakeholder engagement process showed bus operators struggling to explain why services are the way that they are (in terms of routing or service levels); the most common responses were either due to a historical/legacy factor ("it has always been like this") or because they were the specifications sought by the government ("the Department told us to"). One interviewee described the situations as a "grafting on" approach to network planning, where multiple infrequent new routes were layered over existing infrequent routes, with the result being widespread service anomalies such as:

- Some routes have additional peak frequencies whilst others have an all-day flat service level
- Some routes have additional Friday/Saturday evening services, whilst others do not
- Significant variability in route directness and stop spacing between different communities (patronage/coverage trade-off)
- Some circular services are designated loops (with routes describing each direction), whilst other loop services are presented as two terminating linear routes (with buses interlining onto the adjoining route)

It is clear that network structures and designs are excessively ad hoc and often defies "logic", rarely aligning with the government's own policies and priorities. Investigations show that network philosophies depend on the era of the network's planning and implementation (including nuances such as which individuals were part of the network planning team within the Department). A network planning representative shared more about the internal government process, including how they

[21] As an example, there are currently only two metropolitan bus routes which operate every 10 minutes or better across the full hours of each weekday (Routes 246 and 402)—across a city of 5 million people!

would start with a basic scope and when they 'find' additional (or insufficient) budget, they would 'tack on' (or cut) specific trips to alter service span, rather than take a wholescale view to consider frequency or routing changes. One commentator suggested looking to bus reviews conducted in NSW as a good practice, which featured a wholescale recalibration of services on a kilometre neutral basis (Unsworth, 2004).

Other systematic legacy issues identified through the stakeholder ideation include:

- SmartBus, launched in the mid-2000s, is more or less unchanged, despite heavily underutilised sections, poor on-timing running, suboptimal running time allocation and poor service reliability.
- Many routes operate on Saturday at 30-minute headways in the AM and 60 minutes in the PM, representing the Saturday morning shopping legacy of decades past. Today, discretionary demand is probably higher in the afternoon.
- Many routes can benefit from earlier morning services. This is clearly evident where the present first service is the busiest trip of the day.
- Bus/train coordination is particularly poor in the northern suburbs.
- There are cases where routes do not cross railway lines to unlock synergies/connectivity because the networks have not kept pace with level crossing removals or due to a historic legacy where different operators serviced different sides of a rail corridor.

Building trust and tensions in allocating the tactical function

Network reform is a critical upstream measure to 'design out' first/last mile challenges. The difficulty of network reform may be attributed to a lack of resourcing, political interference (e.g., the Plenty Valley network) and tensions in the allocation of responsibilities between the government and contracted private bus operator. Around the world, the allocation of the tactical function of network planning has often been controversial in terms of which party it should be allocated to (or shared between) (Wong and Hensher, 2018). On the one hand, operators are closer to the customer and know their networks/communities. On the other hand, governments may be funding services and have access to more complete datasets. This tension remains in a state of flux and is often not clear-cut. The stakeholder interviews revealed some core issues from several shared 'vignettes'.

One bus operator shared their company's efforts to engage consultants on a network proposal that would better "sweat the assets", unlocking idle bus and crew resources to provide additional services where they were highly demanded. The Department resisted proceeding, but several years later, a new team came on board and requested the same upgrades without memory of the operator-led proposal. These sorts of experiences can be disheartening for operators who take on risks and make investments and can thwart private industry's attempts at being entrepreneurial. A government-held repository of operator proposals and a methodological way to rank, evaluate and determine what is able to proceed would be welcomed.

A Department representative concurred that whilst operator submissions were encouraged, most would have "given up". Officials have also offered scathing views that private bus operators were commercial businesses looking after their bottom line—and can understand their motivations for seeking change. Some examples of cases where operators resisted network reforms were presented, including a suggested desire to fix network problems with additional income rather than a reallocation of existing resources. That said, the Department appeared more likely to consider changes based on operational considerations, such as where driver unions complained about unsafe intersections or roads where buses may have difficulty traversing physically.

Another issue pertains to the exclusivity of market-initiated proposals. Operator proposals are immediately placed to open tender, and this can discourage the industry from coming forward. A more balanced approach may help to nurture initiative and trust.

Operationalising multimodal connectivity

Public transport must itself be integrated as the backbone of a MaaS ecosystem in order for the incorporation of TNC modes to unlock the greatest network effects. This is particularly important in the majority of Melbourne (beyond the CBD and inner suburbs), where service frequency is low. Most of Melbourne's bus services operate at a "policy headway" of 40 minutes, which coordinates with trains operating at 20-minute headways. Research has examined the benefits of longer coordinated headways with shorter uncoordinated headways and how this is dependent on the magnitude of transferring passengers and the disutility placed on waiting time (Currie, 2009).

Bus operators have described timetable coordination projects as "clunky". Bus timetable reviews are undertaken downstream from train timetable changes, with connections often difficult to optimise. Train connections must be balanced with co-scheduling requirements such as offsets, interlining, bus-bus connections, and to meet infrastructure constraints (such as sharing a bus bay or navigating narrow roads). Co-scheduling requirements bring opportunities for enhanced customer service, but their application is often not consistent nor communicated to customers (frequency mapping and branded bus services can help). The Department's service specifications are also often blanket rules and seldom take into account local context, such as how some interchanges are larger in size and require longer connection times (e.g., Williams Landing), as well as the reality of trains being less punctual in the afternoon peak.

The investigation of timetables also showed 'creative' adherence where the 'letter' of a service specification is met, but not the 'intent' of the service specification. As an example, service frequencies may meet the average requirement for a given time window (e.g., the AM peak) but are bunched towards earlier hours, leaving significant gaps in service at later hours within this peak window. Due diligence must be undertaken in these scenarios. Finally, the focus from the Department has been on being prescriptive, and so operators see coordination as a compliance activity rather than one they feel genuinely invested in. New models of procurement and incentivisation could help foster a market solution to support better multimodal integration.

Serving the urban periphery

The stakeholder liaison revealed network change being almost always reactionary, and this is especially true at many of the case study locations on the metropolitan fringe, where services often lag new developments by several years. This contributes to automobile dependency and undermines the likely success of public transport (since new households have already purchased their cars—as a sunk cost—and become accustomed to this mode of travel).

A number of reasons emerged for the difficulty in serving new estates/communities—beyond financial resources. One constraint is the lack of critical enabling infrastructure as developers seek to build major works (such as a bridge) as late as possible in the precinct development process. Another issue is the difficulty in implementing provisional networks and the lack of ability to change fixed routes once set. One community stakeholder mentioned:

"[If] they want to test a new bus route, for example, they can just launch it and then change the route every week, every month or something; once it is done, it is done, because if they change the route, then all the people in that existing road will say we will complain."

This risk-averse attitude is commonly described as a "no losers policy" and can lead to "analysis paralysis" and prevent timely service for new communities (Cranbourne East was a case in point examined in Section 5.3). One mechanism proposed by a stakeholder involved the private sector (including community groups) taking on the risk of serving new areas. This could mean restructuring current contracts so that there is an in-built demand-responsive transport (DRT) component dedicated to serving growth areas. Stand-in assets (vehicles) and a digital platform can be used to deploy services as needed quickly. The benefit of DRT is that it provides an excellent dataset of origins (to the household level) and destinations to inform the later conversion to fixed-route services as the community matures. Two interviewees pointed to the Cooee DRT service in The Ponds in northwest Sydney (which connects with Sydney Metro Northwest) as an example of a successful model and hailed as one of the most heavily patronised DRT services in Australia.

The role of community transport services

The use of community assets is an untapped opportunity. One of the most expensive components of transport operations are the costs associated with fixed capital assets such as buses and depots. Whilst the use of public transport assets in peak periods is stretched, their temporal utilisation is poor due to high peak-to-base ratios. Many buses sit idle in the depot during the inter-peak (and thus reducing farebox recovery). On the other hand, there exists a large number of vehicles belonging to councils and community transport organisations that are prioritised for service during inter-peak periods (sitting idle in peak periods). A significant opportunity, therefore, exists to pool resources and use assets in a way that can unlock their value during respective underutilised periods. Additional services can be delivered without the necessary capital expenditure otherwise required. MaaS exists as an ecosystem to bring service suppliers together and to coordinate in operationally efficient ways, working beyond the domain of single modes and operators.

Interviewees hailed community transport as a low-hanging fruit opportunity. These services already provide public transport, despite not being earmarked as public transport providers themselves. They serve a niche market and suffer from a lack of general awareness of their offering from the public at large. Bringing them together as part of the public transport ecosystem is not a technical limitation; major metropolitan community transport providers are already technologically ready, with booking and routing applications set up. The challenge revolves around regulatory reform, building trust and nurturing a champion within the government to take on the risk of such an initiative. The stakeholder interviews explored at length Point Cook's WYNBUS trial and the incredible hurdles that were required to be registered as a bus operator for such a short trial service period. One commentator described the situation as:

"State government doesn't have the luxury of being very flexible and adaptable/agile, because of their existing frameworks, regulations, etc."

The evolving ridehailing sector

The difficulty in transcending existing mode-specific rules and regulations also manifests itself in the ridehailing and microtransit sectors. Ridehailing operators are generally well embedded in Melbourne, with a number of local homegrown and international TNCs operating. A major challenge is the fragmentation of services amongst different operators, where significant network economies exist in terms of establishing minimum vehicle/driver densities to provide acceptable wait times to customers.

Multihoming describes the ability for users to compare and book multiple ridehailing TNCs within the one application and for drivers to work simultaneously for multiple TNCs, depending on trip availability. This helps to balance both the demand for trips and the supply of rides (Liu et al., 2017), thereby improving social welfare. Larger TNCs like Uber have tried to prevent their drivers from multihoming so that their more extensive 'exclusive' network of drivers can serve as a product differentiator. Banning multihoming has now been outlawed in some markets like Singapore as a condition of entry for ridehailing TNCs. Multihoming can also allow surge pricing to work more effectively to balance demand and supply.

Since 2018, pooled ridehailing (e.g., UberPool) has come online in Melbourne as a cheaper service offering but focused on the CBD and inner suburbs with sufficient ride density. Aggregating pick up and drop off locations to 'virtual' bus stops (in the same way as microtransit) can offer even greater efficiency gains. Pooled ridehailing, however, has been temporarily suspended during the COVID-19 pandemic in light of biosecurity concerns.

New models of ridehailing are beginning to come online, which transcend the traditional focus on point-to-point trips and the peer-to-peer 'gig' economy model (with drivers becoming employees instead). An interviewed entrepreneur noted that 68% of ridehailing trips are currently prescheduled, and 85% repeat users, debunking the belief that many such trips are necessarily spontaneous. This offers the opportunity to book and route trips in 'buckets', enabling more efficient operational management (with savings passed on to the end-user). Embedding more elements of rigidity (away from the dynamic and real-time nature of UberX) can minimise idle and deadheading time. Driver remuneration based on active hours on the platform rather than revenue trips can also better incentivise shorter trips supporting first/last mile multimodal travel (but existing enterprise bargaining awards have been a hurdle to enabling this).

A recurring theme was that many government fees and charges were based on generating revenue rather than enabling what is necessarily equitable and supporting efficient travel mode choice. Presently, the $1.05 per trip levy for commercial passenger vehicles[22] combined with existing driver revenue models makes longer trips more lucrative and is not conducive to encouraging short ridehailing trips to proliferate.

Unlocking the benefits of carsharing

A number of fleet-based (e.g., GoGet, Flexicar, PopCar, Green Carshare) and peer-to-peer (e.g., CarNextDoor, DriveMyCar) exist in Melbourne, but services are generally limited beyond the inner and middle suburbs. The Melbourne experience shows that one carsharing vehicle can replace up to 10 privately-owned cars, with carsharing members exhibiting a 50% reduction in vehicle kilometres travelled due to a fee structure that helps drivers rationalise their car use.

[22] This charge is set by the *Commercial Passenger Vehicle Industry Act 2017*.

All carsharing in Melbourne presently operate as return-to-base schemes and so are unlikely to be used in a first/last mile or inbound travel setting. However, outbound travel where a customer takes a train to a station then hires the car for a longer day trip (e.g., for travel to the Mornington Peninsula) may be more appealing. A number of carsharing providers have previously engaged with the Department and Metro Trains Melbourne on the possible allocation of commuter parking spaces in the middle suburbs for carsharing vehicles. GoGet has identified middle ring locales including Bundoora RMIT and Caulfield as hotspots for carsharing use.

A significant opportunity comes from the future development of one-way or free-floating carsharing schemes, allowing people to use carsharing vehicles on demand. The implementation remains difficult mainly due to the fragmentation of local governments (and their respective policies) in an urban area, the treatment of parking charges, caps on the number of cars, definition of the geofenced area, and (most importantly!) political will.

Micromobility and its potential

Around the world, micromobility (and in particular, e-scooters) is the most heavily regulated new mobility mode. In Australia, micromobility operations are based on a permit acquisition tender process rather than open entry (in the way that ridehailing operates). The number of players and length of permits are heavily restricted, along with rules and regulations governing vehicle registrations, insurances, liabilities and the location of operations (bikesharing now also operates on this basis). Victoria is in the process of adopting the National Transport Commission's reforms to trial dockless e-scooters, with Appendix A12 providing the draft legislative framework for the enablement of micromobility currently being considered. Three metropolitan (inner city) councils have been selected, together with one regional council. [23]

The challenge exists in moving beyond trials and into permanent programs, especially considering how services integrate with other modes. This is particularly difficult given micromobility reports to local government (as opposed to state with public transport). One of the opportunities is in scaling up operations into areas where micromobility can bring a real transport benefit. Micromobility in the inner suburbs is heavily skewed towards recreation and casual trips (in many cases even cannibalising public transport use). In outer suburbs, there can be a significant equity and social inclusion focus in an otherwise transport desert. One method the government can adopt to encourage services in outer suburbs is to implement more complex policies for pricing the public right-of-way (i.e., permit fees for scooters). Auckland, as an example, has three tiers of permit fees that reflect the expected lower demand and vehicle utilisation in the outer suburbs. Subsidies (in effect, negative permit fees) can also be considered to support this low-cost, high-benefit, first/last mile travel option. This aligns with the way previous generations of docked bikesharing have been procured (e.g., Melbourne Bike Share)—on a gross cost operating model and supported by advertising revenue.

Physical infrastructure requirements

In addition to physical services, there is also the need for appropriate physical infrastructure and consideration of marketing and communications as part of MaaS integration efforts. This involves building convenient interchange designs which reduce the pain points of transferring between modes.

[23] These are the Cities of Melbourne, Yarra and Port Phillip, as well as Ballarat.

Not only do schedules need to align, but reducing walk distances (and gradients) can reduce the transfer penalty. Perth, as an example, has placed bus stands within the paid areas of some stations, eliminating the need to tag out and then back in. Bus and train transfer is even available at Kelmscott station (southeast Perth) via a rarely seen cross-platform arrangement.

Joining services (particularly TNC modes) in non-interchange locations can also be a cause of friction. Finding a ridehailing vehicle in heavy traffic or a place to park on a high-speed arterial are cases in point. The City of Waverley in Sydney has trialled PUDO (Pick Up Drop Off) areas at key locations with variable success. Kerbside management is likely to become an increasing issue with the greater use of shared services and the advent of autonomous vehicles in the future. The provision of active travel networks to reach bus stops (virtual or physical) is also critical.

Interviewees suggested the provision of wayfinding as a major weakness in Australia due to the fragmentation of responsibilities between transport authorities (within interchanges) and other signage within the remit of the council or road authority. New mobility modes have rarely been incorporated into pedestrian signage. The changing mobility landscape is democratising transport such that public transport becomes not only mass transit but all non-private ownership modes.

Reforms in the future could include an overall network name or brand that encompasses both public transport and TNC modes. This is closely aligned with the idea of the broker and digital infrastructure requirements discussed in the next section.

6.5. Digital infrastructure requirements

One of the essential components of MaaS is the technology layer which brings together different service providers and delivers an integrated product offering to customers. This function is undertaken by what is essentially the MaaS broker/aggregator, and this ‘conduit’ requirement may range from a simple display of service availability/information, to providing a booking/payments mechanism, or as complex as selling subscription bundles and optimising service supply according to changes in demand (aligning with the Sochor et al. (2018) layers of integration).

MaaS is not a “protocol”, but rather an aggregation of different standards, protocols, specifications and algorithms. Figure 32 collates some of the essential data requirements as part of the ecosystem. Interviewed respondents shared some of the critical enabling requirements and pointed to good practice reforms in jurisdictions such as Finland—including mandating the third-party resale of public transport tickets, requiring collaboration between parties and the establishment of a data custodian/repository—all for the public’s benefit. The overwhelming sense amongst interviewees was that difficulties in facilitating MaaS was not due to technological limitations, but rather the result of a deficiency in trust, regulation and governance:

> *“Several hurdles must be overcome for mobility data to unlock its (huge) expected value: the lack of trust between the different players in the highly competitive urban mobility market, the need for standards enabling interoperability, and a level playing field setting the legal, regulatory, and technical conditions for effective, secure, and fair data sharing (and monetisation).” (Laborda, 2021)*

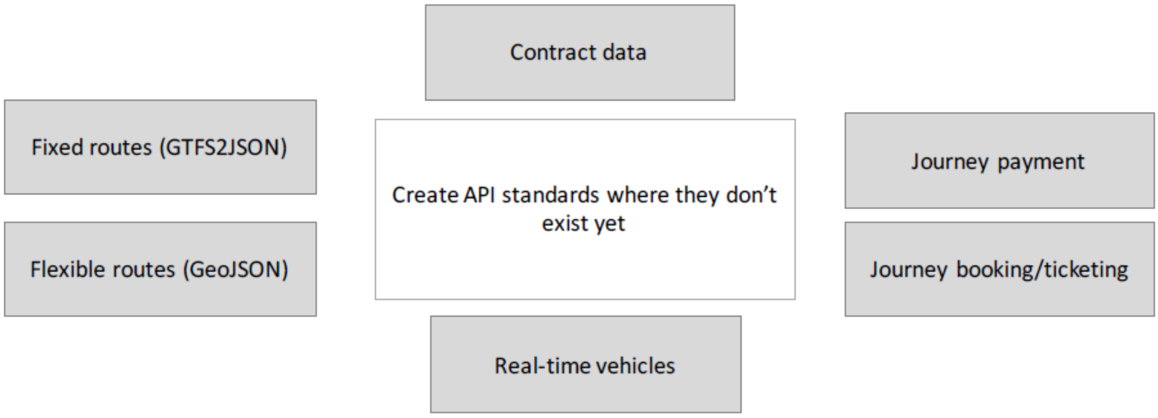


Figure 32: Minimum data and application programming interface (API) requirements to support MaaS integration (Kamargianni and Matyas, 2017: 9)

Data fragmentation and interoperability

Different operators having their own data formats, geospatial capabilities, underlying base maps, telemetry systems, mobile applications, and public-facing websites bring ongoing coordination complexities. This is compounded by many datasets (e.g., tracking) having multiple references and no single definitive 'source of truth'. This makes it difficult to integrate data easily.

MaaS is based on the exchange of static and real-time data and requires interoperability and integrated systems within a framework of secure data sharing and harmonisation at regional and national levels. Data standards need to consider how data is collected, processed, shared, and stored, as well as its quality, accuracy, format, frequency and privacy guidelines. Privacy, in particular, can be controversial, as the definition of what is personally identifiable information changes rapidly. The European Union's General Data Protection Regulation (GDPR) provides one of the strictest definitions of privacy (Cottrill, 2020).

Cities worldwide have adopted a wide range of data standards (Appendix A13 details a list of the main MaaS data sharing protocols). The General Transit Feed Specification (GTFS) and General Bikeshare Feed Specification (GBFS) are some of the most ubiquitous, de facto standards. A recent new addition is the Mobility Data Specification (MDS), built on GBFS and pioneered in Los Angeles in partnership with the micromobility industry. MDS standardises data sharing and communication between city authorities and TNCs, and supports cities in their sharing, validation, management, and enforcement activities.

Trust architecture models

Discussions with the Department revealed that Victoria's data-sharing ecosystem is far from mature. Whilst the Victorian government has an "open data policy", specifications are not fully compiled nor defined. Data sharing remains ad hoc and project-based rather than holistic. NSW was pointed to as being more advanced, with a dedicated open data team that look after the datasets and their publication. Data sharing is challenging internally within large organisations with many "verticals", but the complexity is multiplied manifold when dealing with third-party stakeholders and in the context of MaaS, where so many services and data generators exist outside of government.

Whilst contracted public transport operators are private entities, they operate in a competition *for* the market setting as extended public servants with a protected area monopoly for a defined period of time. The sharing of data is a given in contracted environments where it is stipulated as part of an agreement. The data is essential for determining the private operator's remuneration and for the government to implement actionable benchmarking, including the administration of incentives and penalties linked to operator performance.

TNCs operating in an economically deregulated, competition *in* the market scenario are not directly remunerated by the government. Their business models are predicated on collecting, mining and selling users' data. TNCs are extremely reluctant to open their data, unless it is a regulatory requirement or the right incentives are in place to support their commercial objectives. In the Victorian case, vendors frequently approach the Department with the offer to sell their datasets (such as cellular, parking, and even bike cage usage). However, these are self-motivated, commercial relationships premised on money exchange rather than for mutual benefit. Balancing commercial/public interests and building a trust architecture and data sharing framework is required to bring these parties together and to facilitate the information sharing, trust and collaboration required to operationalise MaaS (Wong, 2019).

Table 20 presents several options for such a framework. The Victorian case most closely resembles Scenario 2, where TNCs aggregate data and provide this to the authority for 'optics' and auditing purposes. Highly aggregate datasets such as Uber Movement provided globally is not inherently useful for MaaS applications. Scenario 3 describes a case where TNCs provide raw datasets to the government for aggregation. This has been standard in the case of MDS datasets and in the heavily regulated micromobility sector (likely also to be a requirement for the e-scooter trials in Victoria). In this setting, the authority takes on the responsibility of the MaaS broker/aggregator. TNCs need to be compelled/incentivised to share and be reassured that their competitors must also play by the same rules.

Trust issues can arise where TNCs share data with the government but are also regulated by the same data that they share. This may be particularly problematic where datasets that are provided to facilitate MaaS and to realise customer-facing benefits are also used by the government for compliance and enforcement purposes. Scenario 4 provides an alternative where TNCs provide the necessary data to a third-party intermediary independent of the government. A private data analytics platform can provide such services, though there exists the very real risk of vendor lock-in (the outsourcing of public transport smartcard ticketing systems is one example where this has occurred).

The final example (Scenario 5) describes a case where any number of third-party MaaS platforms operate in the market. TNCs undertake bilateral relationships with the aggregator to provide integrated services (they can even take on the role themselves). This can lead to a fragmented ecosystem but is also a more readily achievable scenario driven primarily by commercial interests. Examples of such a scenario (e.g., taxis or bikesharing integrating with a journey planner) are already emerging in Melbourne. Given the third-party status of the aggregator (independent to government), how datasets under the custodian of the government may be integrated remains unresolved.

Table 20: Trust architecture scenarios (Laborda, 2021)

Scenario	Trust architecture and data sharing approach	Example
1	No data sharing	
2	TNC aggregates data and provides it to the authority	Uber Movement (globally)
3	TNC provides raw data for the authority to aggregate	Micromobility in Los Angeles (via MDS)
4	TNC provides raw data for a trusted third party to aggregate on behalf of an authority	Services provided by third-party vendors (e.g., Google)
5	TNC provides datasets to a third-party vendor, which operates in an open market to provide MaaS services	Third-party MaaS player (issue is how public transport will integrate)

Extending the PTV journey planner and Myki ticketing interface

A major point of contention relates to whether the public or private sector should assume the role of the MaaS broker/aggregator (Scenarios 3/4 and 5 in Table 20). Questions/concerns around technical capabilities, the ease of integration, and the willingness/trust of suppliers to integrate emerged as key issues in the Victorian context. Should the government take on the integration role (as is the case in Berlin and Tel Aviv), it can make use of the existing PTV journey planner and Myki ticketing interface. According to the Department, the PTV application enjoys a healthy 30% market share in Victoria. This complements around 50% who use Google Maps (similar to most Western cities) [24], with the remainder using third-party or operator-specific applications (such as TramTracker). The PTV application has been upgraded in recent years with additional functionalities, including walking/cycling modes, but the incorporation of new mobility modes remains elusive.

Two questions need to be considered when transforming the PTV journey planner into a multimodal application interface: (i) the public interest in terms of what customers wish to see in the application; and (ii) the community interest around which TNCs are willing to partner and to be incorporated within the application. The first question generally encompasses all complementary modes with the possible exception of carsharing (on the urban periphery, there are a limited number of options to be integrated regardless). The second question is one that is more difficult and varies significantly between operators of different modes and sizes.

Larger operators benefiting from market domination often have everything to lose in sharing their ticketing products and timetabling information (thereby giving their 'captive' passengers more choice), compared with smaller operators who can grow market share by attracting competitors' passengers. Modes such as micromobility operating in heavily regulated environments generally bring a different approach to ridehailing with its greater "winner takes all" consideration. In many cases, private operators are eager for public transport (or the government) to integrate with them but are wary of integrating with public transport (or the government). In this way, they are able to maintain the crucial ownership of (and interface with) the customer.

[24] In Sydney, as an example, TripView has a very high market share because it predated the official application. This is a special case where even a large proportion of the public believe TripView to be the official government-provided public transport journey planner.

Developing a regulatory framework to enforce collaboration can be helpful, as adopted in Nordic countries or the wholesale model seen in other utilities like electricity and telecommunications (separation of the provision of capacity with the customer interface). These are considerations for the Department to work through, as an overall, consistent approach/framework (extending beyond transport) delivers the most significant end-user benefits.

The complexity of integration is also dependent on the extent of integration necessary. The provision of multimodal information can demand less sophisticated data sharing than booking/payments integration and the sale of subscription bundles. A deep link that passes information from one application to another (e.g., pre-filling data for a taxi booking itinerary) can be developed far more easily (and sometimes even unilaterally) than a native integration alternative where information must pass in two directions.

Myki, as the public transport ticketing and payments system, is a critical component of any MaaS integration (noting that Victoria is embarking on a journey to procure a next-generation ticketing solution). Interviewed stakeholders mentioned that technical limitations were not a concern for launching debit/credit card payments or extending Myki as part of a digital mobility wallet that can also be used for payments on TNC modes. The provision of transfer discounts (e.g., with Opal Connect in Sydney) can help entice TNCs to partner with the government. The greatest challenge is in dealing with business considerations such as revenue sharing and ownership of customer databases and other information of commercial value.

Enabling third-party MaaS ecosystems

A recurring theme posed amongst interviewees was whether the government saw itself as a transport services integrator. The lack of clarity and signal to the market can affect the private sector's attitude and positioning. A Department official noted that the government aimed to provide a "great customer experience" and suggested that as the market becomes more mature, then the Department can consider whether it becomes more of a backend enabler and data provider, leaving the customer engagement channel/interface to the private sector (a path many jurisdictions have traversed upon).

One of the findings from the interviews was that the way government engages with private sector integrators has been inconsistent. Several third-party technology integrators have attempted to add additional public transport functionalities within their applications. One developer sought an API for real-time information and journey fare estimates (on the expectation that it would be free). A Department official suggested that this provision could bring risks to the government, including possible reputation loss and even traffic spikes, which would bring down Department services. PTV already publishes a timetable as part of its API but does not provide additional support services.

Another vendor (RACV's Arevo), as a work-around, developed a screen-scaping tool to provide a Myki top-up function within its application (this has since been discontinued). Interview participants noted that the Department is selective in choosing whom it partners with, citing the example of the Department investing in backend infrastructure to integrate with Google (this can be construed as a private API), simply because of their higher market share. There was some consensus that smaller technology players are disadvantaged and not able to receive what they want. One technology developer noted:

> *"You must go through [the Department] for everything, but [they] can't do anything for you."*

The provision of APIs to third parties is not an inexpensive endeavour. Transport for NSW, as an example, pays Mentz as the aggregator a monthly fee to publish publicly available public transport APIs. A Department official suggested that a business-to-business contractual partnership should be established with interested third parties, with a payment made to guarantee data services and provide a 24/7 support package (complete with service level agreements). The Department could start by establishing a catalogue of services and fees that it can offer to all third parties so as to negate the need to negotiate with individual vendors. This type of consistency of approach can aid ecosystem development and maturation.

To further facilitate an open MaaS ecosystem with different vendors, public transport can be reformed to accept mobile (or m-) ticketing, greatly enhancing flexibility. M-ticketing solutions can now provide a ticketing solution that is infrastructure-light and on-par with the data accuracy from smartcard ticketing systems. Without m-ticketing, Queensland's ODIN PASS has had to use a flash pass as a workaround, and Sydney's Tripi was based on a compromised solution of issuing branded Opal cards for users, which were linked in the backend to their MaaS accounts (Table 3 provides a more comprehensive overview).

While the PTV application continues to be unique in terms of its public transport functionalities and Myki integration, third-party solutions have better multimodal integration functions and a suite of features that technology developers have been able to invest in due to economies of scale from being global enterprises. However, digital solutions by themselves are not a panacea for a great multimodal experience. Providing information for disruptions and even dynamic routing can be of limited use to customers who have already been delayed. The most significant opportunity of MaaS in a more connected and collaborative data/information ecosystem is how demander characteristics may be looped back to inform service supply—both in the short term

INNOVATION IN FOCUS: AREVO MYKI TOP-UP

The Royal Automobile Club of Victoria (RACV) undertook in 2018 to diversify its business strategy by launching an extended journey planner called Arevo (marketed publicly as MaaS). Several value-adding components were incorporated, including a display of cycling infrastructure, real time parking information, a link to a carsharing provider, and links to retail offers (including RACV's own insurance products). The platform backend was provided by SkedGo (subsequently replaced by Intelematics).

Market research found the Myki ticketing customer experience to be suboptimal, especially the online top-up functionality (with many people resorting to top-ups at the train station which was far more convenient).

Opportunities to enhance the public transport component was limited, because of a closed Myki ecosystem. The Arevo team hence built a 'screen scraper' which allows customers to provide inputs (e.g., credit card details) natively in the Arevo application, which then pushes this in the back-end through the Myki website, filling out relevant details in a PCI-compliant and secure way.

The Department of Transport was lukewarm about the process and was concerned about security and possible errors (including potential instances of website time-outs and double-charging). After several website upgrades, the feature has since not been available, and progress continues to be pending on a new initiative to allow third-parties a more robust, quicker and more secure way to interact with the Myki interface.

through operational management and the medium term to inform network planning. MaaS can help support adaptive, contingent, and reliability-based insights back to transport operators and optimise their service offerings via machine learning to provide real-time, robust and more agile transport services.

6.6. Governance/procurement requirements

As evident, nurturing digital infrastructure for MaaS is highly dependent on trust, collaboration and regulation. The governance of the transport ecosystem can be the single greatest enabler/hindrance of integration. Interviewed respondents considered the state of play in Victoria around the role of government in nurturing collaboration, the fairness and suitability of regulation, as well as government priorities, funding and support. These views were mainly shared from a third-party private enterprise perspective.

On working with government

Building on the difficulty in obtaining public transport APIs, TNCs and technology providers described high staff turnover and the complexity of the bureaucracy as a hindrance to engaging with the government, particularly in bringing forward proposals that may have a public interest and work in good faith to interface with public transport. One stakeholder was almost despondent and described difficulties in knowing whom to approach. Another respondent shared that at the Department:

“The left arm doesn’t know what the right arm is doing.”

Developing an avenue for government/industry engagement is extremely important with the democratisation of transport services and the increasing fragmentation of data custodians. A platform for market-led proposals which are problem-focused and places the government and private sector on a genuinely equal footing can nurture innovation. Bringing the principle that the government does not know best and presenting the industry with problem statements (Transport for NSW has developed this through Innovation Challenges) can be an alternative to prescriptive and unidirectional expressions of interest processes that might hinder blue-sky thinking. A rigorous assessment must still be carried out in this regulated platform to ensure fairness and value for money.

The way in which these programs are run is critical. A technology vendor who worked with multiple state authorities mentioned that some engagement programs had an underlying objective to take industry secrets which are then developed and deployed internally by the public sector:

“They take what you told them, then do it by themselves.”

On government priorities and investments

Stakeholders presented a scathing view on how the government chose the projects it wanted to fund. Demand-responsive transport was one example where Rowville's FlexiRide was selected without community consultation nor due process. Respondents noted that there was a skew in focus on innovation over cost management, as well as a preference for capital expenditure over recurring, which increased the business-as-usual operating budget. The politics of appearance was given more credence over the substance of the outcomes:

> *"Technology is now driving service design, distinct from the need to put bums on seats."*

Stakeholders suggested that building momentum amongst officials who were not technocrats was essential. Identifying champions within government (and especially Treasury) was critical, as well as tying into Victoria's Big Build projects as catalysts for change.

Harmonising the regulation of new mobility modes

Around the world, cities failed to act quickly to capitalise on the growth of the ridehailing sector and to develop the governance and data sharing frameworks to regulate TNC operators. Having learnt from this experience, the micromobility sector is now governed in a vastly different way in terms of the granting of permits (free entry vs. regulated), permit fees and requirements to share datasets for compliance purposes. It is difficult to make a case for why different TNC modes are treated substantially differently. A similar argument may also be made for small vehicles and whether they are provided as commercial or contracted microtransit (including how drivers are remunerated). The present approach exacerbates inefficiencies, wasteful competition/duplication and hinders effective integration.

Treating all modes with the same open data principles, implementing regulations to enable multihoming and reducing barriers to entry and perceptions of bias is critical. Nurturing a level playing field and implementing mode-agnostic regulations which are not dependent on the format of vehicles can enhance service provision and equity. The provision of funding support and subsidies should also follow this more mode-agnostic service delivery model.

The role of funding and subsidies

The current contractual regime and funding model embeds mode-specific inefficiencies. Subsidies are paid based on intermediate objectives (such as service kilometres) rather than the ultimate objective of greater mobility/accessibility for the end-users. To support integration, the government can move to a dynamic payments model and incentivise trunk mode operators to partner with TNCs by providing greater patronage incentives. The government can also consider subsidising new mobility modes to deliver services to areas of need, such as the metropolitan fringe. This was the norm with the majority of docked bikesharing systems around the world prior to the emergence of venture-backed e-scooter and e-bike companies. Public subsidies for TNCs can replace bus funding where greater value for money can be demonstrated (or paid to any entity to provide services with any mode under a mode-agnostic mobility contract regime).

The fundamental reform of procurement and funding of transport services through multimodal MaaS contracts (including via an open tender) where units of 'mobility' are purchased ensures freedom for the market to deliver services using the most cost-effective and geographically appropriate mode of transport. To support third-party MaaS providers and the wholesale ecosystem described, the government needs to sell public transport capacity to the integrator with a quantity discount, as well as supporting emerging multiservice models (linking MaaS with lifestyle, retail and property products). This helps the integrator meet the costs and risks of technology provision and in taking the role as the interface with the customer. Opportunities to cross-subsidise between modes and to internalise positive externalities (e.g., via the land use connection such as linking with reduced parking provision requirements for developers) can also assist.

The promise of MaaS in optimising transport networks stems from when pricing strategies (including the provision of subsidies) are used to nudge travel behaviour, including the time and mode of travel. In this world, the government needs to better link subsidies with ways to measure social benefits and direct taxpayer funds to where they can deliver the greatest end-user and societal benefits.

The role of government in a future transport ecosystem

The private sector is playing a growing role in the ownership of assets, provision of technology platforms and datasets, and the operation of new mobility modes which complement public transport. There is an increasing shift in the dial between public and private sector responsibilities, and around the world, transport authorities are rethinking their position in the transport ecosystem.

The Department of Transport's new strategic context is one step to developing the policy/regulatory framework in an emerging transport paradigm. Organisational culture change towards "fast fail" can guide this, as well as the provision of regulatory sandboxes to trial upcoming business models. Research shows the private sector prefers strategic support over heavy-handed approaches and expects the government to not "stand in the way of innovation" but nurture competition and ensure a level playing field (Wong et al., 2019). Whether the government chooses to be a key driver/leader or a backend enabler in this brave new world remains to be seen.

7. MaaS options and roadmaps

7.1. MaaS options generation

Summarising Chapter 6, the main barriers and facilitators for implementing MaaS in Melbourne are collated in Table 21 according to requirements at different integration layers. The summary shows key challenges but also opportunities for how each layer might be addressed as part of a move towards a MaaS ecosystem.

Table 21: Key challenges and opportunities at each layer for implementing a MaaS ecosystem

	Barriers	**Facilitators**
Physical service requirements	Fixed route network suboptimal; TNC modes do not yet exist to be integrated	Clear need for better first/last mile connectivity
Collaboration requirements	Vested interests of operators; Lack of government engagement/support channel	Strong market entry desire amongst TNC operators; Interest in new models of public/private collaboration
Data sharing/trust architecture	Lack of an appointed third-party aggregator or data custodian; Current sharing approach is ad hoc	Role of data sharing is recognised, including the need to establish a consistent framework
Payments/ticketing requirements	No contractual model for Myki integration with third-parties services	No fundamental technical limitations in opening up Myki and the PTV journey planner
Governance requirements	Lack of clear strategy on the role of government in a MaaS ecosystem	Appetite for reform and development of a new strategic context

These findings and the stakeholder ideation process helped inform the development of a series of scenarios or futures for addressing transport connectivity and integration in Melbourne. These future MaaS scenarios are not mutually exclusive but rather exist with an infinite number of permutations depending on a large variety of attributes and design possibilities. Taking a values-based approach based on addressing what was identified by stakeholders as key variables and desired policy outcomes can help keep the number of options manageable and maximise relevance for Victorian stakeholders. Six MaaS options (Models A to F) were hence generated, which represent a 'slice' of an infinite continuum. These range from actions directly addressing first/last mile connectivity to a series of MaaS Lite and Full MaaS alternatives (led by the government or third parties), as well as how MaaS might be facilitated via a full market resolution. An overview of these models and their key characteristics are provided in Table 22.

These six MaaS options should be considered with reference to Figure 33, which provides a decision matrix to aid selection and links each model to clear objectives and criteria. The matrix branches depending on the immediacy and directness of intervention for solving the first/last mile challenge. Transport connectivity can be targeted via direct action or by facilitating MaaS which can indirectly support better first/last mile integration. The matrix further branches depending on the ease (or speed) of implementation, as well as the role of the government in the MaaS ecosystem. The six models, whilst discrete, are only one way of partitioning a complex set of attributes. Some dependencies exist amongst the models, although others may be treated in isolation. For instance, addressing network reform (Model A) should be a precursor to implementing Models B to E, whilst facilitating a third-party Full MaaS ecosystem (Model E) is necessary to support Model F.

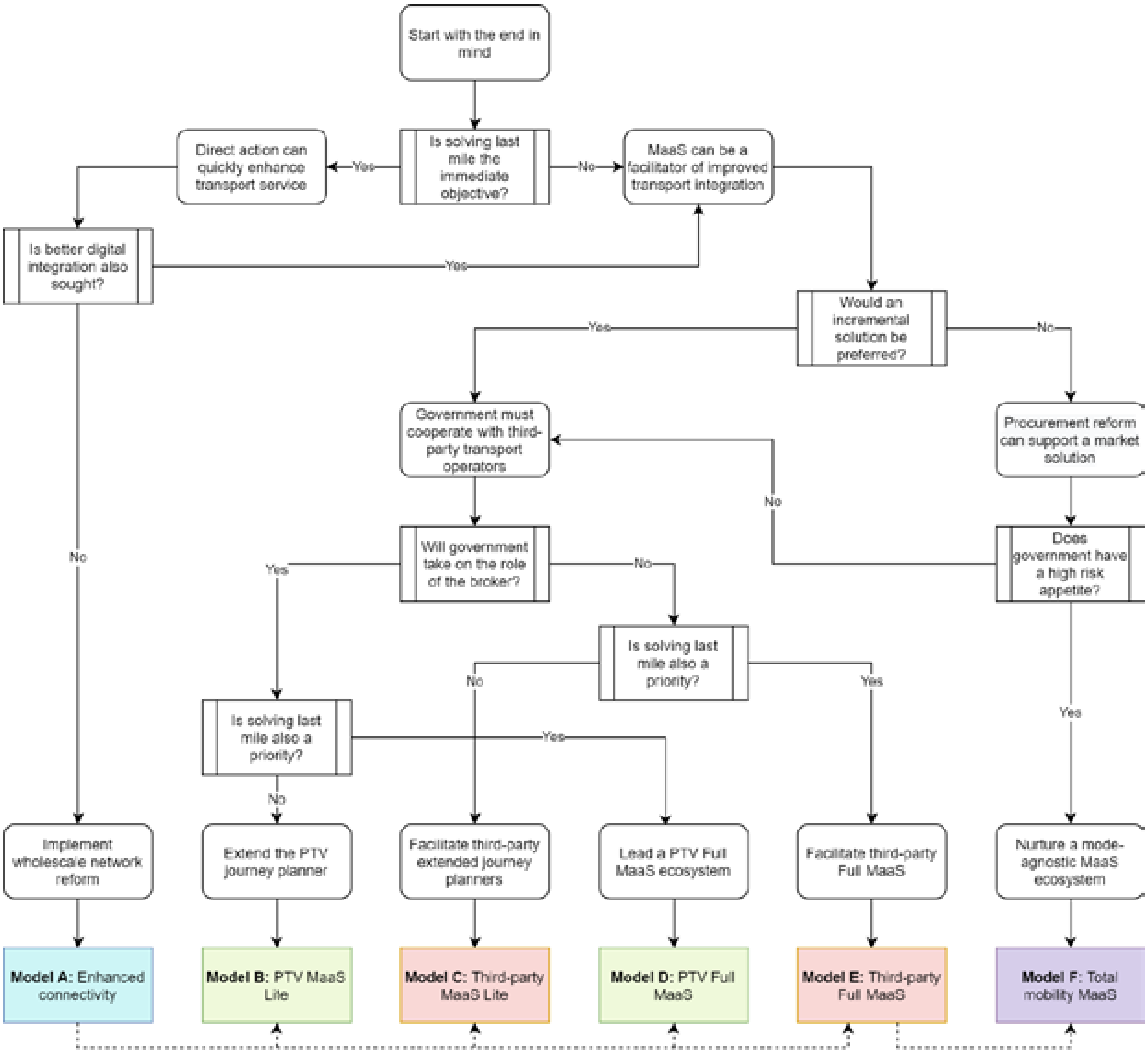


Figure 33: Decision matrix for the choice of first/last mile and MaaS reform options

Targeting efforts at the earliest upstream intervenable point ensures that policies do not clutch at low hanging fruit without addressing root causes and symptoms. The MaaS options have been structured according to this priority and are again motivated by the Sochor et al. (2018) hierarchy of MaaS integration levels: physical service, information, ticketing, subscriptions and governance. For example, it is better first to reform the public transport network to optimise the service offering and ensure that a given level of service maximises service availability before supporting (and even subsidising) TNC services to 'plug gaps' within this network. Similarly, bundles and pricing incentives should build upon this reformed network to maximise benefits to the end-user, as well as ensure that government outlays (e.g., to support DRT or TNCs) are spent effectively.

Each reform option is accompanied by a series of roadmaps with a set of suggested innovations for each priority and implementation phase. A comprehensive innovation plan has then been developed that brings together the roadmap actions into nine themed innovations, each consisting of a series of steps further outlined in Chapter 8. These nine innovations are additionally grouped into three categories, targeting physical service, digital infrastructure and governance/procurement.

The remainder of this chapter provides detailed roadmaps for each of the six MaaS options:

- Section 7.2 (Model A) illustrates an enhanced connectivity scenario that prioritises network reform to address accessibility gaps, delivering more agile services on the metropolitan fringe, and improving the equitable deployment of TNC services like ridehailing, carsharing, microtransit and micromobility.
- Section 7.3 (Models B/D) shows a government-led MaaS ecosystem where the PTV application becomes an extended journey planner (MaaS Lite) or true MaaS integrator (Full MaaS). A new data-sharing framework and trust architecture model encourages TNCs to participate in the government-led ecosystem, whilst new Myki functionalities enable it to operate as a multimodal digital wallet.
- Section 7.4 (Models C/E) displays a private sector-led MaaS ecosystem where government facilitators third-party integrators by releasing public transport application programming interfaces (APIs), thereby supporting MaaS Lite. Under Full MaaS, the third-party resale of Myki tickets and the introduction of mobile ticketing further supports seamless public transport and TNC connectivity.
- Section 7.5 (Model F) presents a full market resolution where transport services are procured on a total mobility basis. When fully implemented, the MaaS integrator is procured based on delivered accessibility under a real-time monitoring framework. Multimodal integration is endogenised, as the mobility custodian is able to deliver services using any mode (and combination) of their choosing.

Table 22: Overview of each first/last mile and MaaS reform options

Implementation models		**Model A Enhanced connectivity**	**Model B PTV MaaS Lite**	**Model C Third-party MaaS Lite**	**Model D PTV Full MaaS**	**Model E Third-party Full MaaS**	**Model F Total mobility MaaS**
Objective		To address first/last mile challenges by facilitating additional physical services	To establish the PTV app as an extended journey planner	To facilitate a third-party app as an extended journey planner	To establish the PTV app as a one-stop travel management platform	To facilitate a third-party app as a one-stop travel management platform	To build a mode-agnostic MaaS ecosystem where the private sector acts as a total mobility provider
Equivalent integration level (Sochor et al., 2018)		0	2	2	3	3	4
Implementation difficulty		Medium	Medium	Low	High	Medium	Extreme
First/last mile benefit		High	Low	Low	Medium	Medium	High
Role of public/private sector		Full government resolution	Government-led	Market-led	Government-defined	Market-defined	Full market resolution
Integration category	**Sub-category**						
Physical services (Level 0)	Public transport	Government-led reform	Existing network	Existing network	Reform opportunities	Reform opportunities	Market-led reform
	New mobility modes	Government-enabled additions	Existing services	Existing services	Market-led additions	Market-led additions	Market-led additions
Information (Level 1)	Trust architecture		Public	Third-party	Public	Third-party	Third-party
	Data sharing		Likely bilateral	Likely bilateral	Multilateral	Multilateral	Multilateral
	Digital platform		Public	Third-party	Public	Third-party	Third-party

Implementation models		Model A	Model B	Model C	Model D	Model E	Model F
Booking and payments (Level 2)	Booking capability		Deep-link	Deep-link	Native	Native	Native
	Payment capability		Myki-first	Digital wallet	Myki-first	Digital wallet	Digital wallet
	Payment format		Mixed	Mobile-first	Mixed	Mobile-first	Mobile-first
Service offerings (Level 3)	PAYG design				Multimodal discounts	Multimodal discounts	Multiservice opportunities
	Subscription bundles				Market defined	Market defined	Market defined, governance overlay
Governance (Level 4)	Funding				Possible operator subsidies	Possible operator/broker subsidies	Redefinition of funding unit
	Procurement				Mode-specific	Mode-specific	Mode-agnostic

7.2. Model A: Enhanced connectivity

Model A: Enhanced connectivity				
Priority	**Short term (1-2 years)**	**Medium term (3-5 years)**	**Long term (5-7 years)**	**Destination**
How can the present public transport quantum of services provide the maximum coverage benefit?	1a. Commence a comprehensive analysis of public transport accessibility 1b. Identify external catalysts for network reform 1c. Establish a multicriteria ranking to prioritise reform implementation	1d. Work in partnership with transport operators and community stakeholders to deliver a network reform implementation plan	1d. Work in partnership with transport operators and community stakeholders to deliver a network reform implementation plan	Greatest mobility value provided for a given service kilometre outlay
How can public transport services be better integrated (within modes)?	2a. Define frequency and span requirements at each hierarchy tier 2b. Allocate routes and cross-check service levels in line with stated policy	2c. Ensure service level definitions are applied consistently across different communities 2d. Ensure greater rigour in the application of service specifications and coordination requirements	2e. Make publicly available datasets showing how each community meets service level requirements	Improved coordination amongst contracted public transport services
How can transport services be provided with great agility on the urban periphery?	4c. Encourage new mobility offerings on the metropolitan fringe 3a. Assign a standby DRT technology provider for each growth centre 3b. Develop a database of underutilised community vehicle assets and service capabilities	4d. Review and channel developer contributions 3c. Implement DRT services as new residents move in (within weeks) 3d. Ensure active monitoring of service performance and travel behaviour	3e. Mature services with a fixed route bus offering (within years) and scale assets to new growth areas	Better (and immediate) transport services on the metropolitan fringe

Priority	Short term (1-2 years)	Medium term (3-5 years)	Long term (5-7 years)	Destination
How can TNCs be incentivised to provide services in the middle and outer suburbs?	4a. Establish an easy approach avenue for private sector operators and technology providers to engage with the government 4b. Develop a template to design, implement and evaluate trial services 4c. Encourage new mobility offerings on the metropolitan fringe	4d. Review and channel developer contributions 4e. Consider the role of public subsidises in supporting equity in the deployment of new mobility modes	4d. Review and channel developer contributions 4e. Consider the role of public subsidises in supporting equity in the deployment of new mobility modes	More equitable access to new mobility modes

7.3. Models B/D: PTV-led MaaS Lite/Full MaaS

Models B/D: PTV-led MaaS Lite/Full MaaS				
Priority	**Short term (1-2 years)**	**Medium term (3-5 years)**	**Long term (5-7 years)**	**Destination**
Recommended: All priorities in Model A				
How can we foster trust in a public data custodian?	6. Determine the government's role in the MaaS broker/aggregator ecosystem 5c. Appoint a data custodian as an aggregator and intermediary	8a. Review the *Transport Integration Act 2010* with an explicit view to incorporate new mobility modes		Confidence in government as the data custodian
How can TNCs readily integrate with other TNCs and public transport?	5a. Review the regulations governing each new mobility mode and their right to operate 5b. Establish a comprehensive data-sharing framework for the TNC sector	5d. Implement new regulatory requirements, ensuring the consistency of application across each new mobility mode		TNCs governed by a consistent data-sharing framework and standards
How can TNCs be convinced to participate on the PTV MaaS platform?	6a. Market test which operators are willing to participate in a government-led MaaS ecosystem	8b. Provide greater patronage incentive amongst existing mode-specific contracts 8c. Explore user- and supply-side funding support to nudge sustainable travel behaviour	8b. Provide greater patronage incentive amongst existing mode-specific contracts 8c. Explore user- and supply-side funding support to nudge sustainable travel behaviour	TNCs willing to participate as service suppliers to the government as the MaaS broker/aggregator
How can the PTV application host new mobility modes?	6b. Build deep link and native integration capabilities in the PTV application	6c. Establish Myki as a multimodal digital wallet		PTV application able to host TNC information, bookings and payments

7.4. Models C/E: Third-party MaaS Lite/Full MaaS

Models C/E: Third-party MaaS Lite/Full MaaS				
Priority	**Short term (1-2 years)**	**Medium term (3-5 years)**	**Long term (5-7 years)**	**Destination**
Recommended: All priorities in Model A				
How can we foster trust in a private data custodian?	6. Determine the government's role in the MaaS broker/aggregator ecosystem 5c. Appoint a data custodian as an aggregator and intermediary	8a. Review the *Transport Integration Act 2010* with an explicit view to incorporate new mobility modes		Confidence in the private sector as a data custodian
How can TNCs readily integrate with other TNCs and public transport?	5a. Review the regulations governing each new mobility mode and their right to operate 5b. Establish a comprehensive data-sharing framework for the TNC sector	5d. Implement new regulatory requirements, ensuring the consistency of application across each new mobility mode		TNCs governed by a consistent data-sharing framework and standards
How can third-party applications host public transport offerings?	7a. Establish a catalogue of government-held data feeds, service level agreements and fees 7b. Provide open APIs to third party operators and integrators as government policy	7c. Enable the third-party resale of Myki tickets 7d. Enable mobile ticketing on public transport		Third-party MaaS platforms can host public transport information, bookings and payments

7.5. Model F: Total mobility MaaS ecosystem

Model F: Total mobility MaaS ecosystem				
Priority	**Short term (1-2 years)**	**Medium term (3-5 years)**	**Long term (5-7 years)**	**Destination**
Recommended: All priorities in Model E				
How can public transport contracts be redesigned to incentivise modal integration?	8a. Review the *Transport Integration Act 2010* with an explicit view to incorporate new mobility modes 8b. Provide greater patronage incentive amongst existing mode-specific contracts	8c. Explore user- and supply-side funding support to nudge sustainable travel behaviour	8c. Explore user- and supply-side funding support to nudge sustainable travel behaviour	Public transport operators partner with TNCs to provide integrated multimodal offerings
How can future transport contracts endogenise modal integration?	9a. Develop a unit accessibility measure as the underlying key performance indicator 9b. Set a baseline requirement for minimum service levels and the parameters of operation	9c. Design a real-time framework to monitor experienced service levels 9d. Engage the market to design a procurement model to pilot an accessibility-based multimodal service contract in a defined geographic area	9e. Evaluate service performance and value-for-money on a total mobility (mode shift) basis	Transport services are procured under a mode-agnostic paradigm
How can synergies between the transport and lifestyle/retail/property sectors be exploited?	4a. Establish an easy approach avenue for private sector operators and technology providers to engage with the government	4d. Review and channel developer contributions 8d. Encourage the development of multiservice MaaS propositions	4d. Review and channel developer contributions 8d. Encourage the development of multiservice MaaS propositions	Multiservice MaaS is facilitated

8. Proposed innovations

This report has been developed to help inform a series of reform options that provide improved first/last mile connectivity and better integrate public transport and new mobility modes in metropolitan Melbourne. Chapter 6 provided a holistic review of barriers and facilitators to the integration of physical services, information, ticketing and governance, whilst Chapter 7 brought these insights together as part of a series of reform options and roadmaps targeting each integration layer (Table 22). Each reform option comprised of a series of short-, medium- and long-term innovations, which are presented in this chapter, grouped by theme: Innovations 1-4 (Sections 8.1-8.4) relate to **physical service**, Innovations 5-7 (Sections 8.5-8.7) target **digital infrastructure**, whilst Innovations 8-9 (Sections 8.8-8.9) improve **governance/procurement**.

There can be a misguided belief that technology is a panacea for mode shift and solving constraints of physical service such as first/last mile integration. A recurring theme throughout this report has been that technology is a necessary but not sufficient condition for MaaS. Technology should be an overlay upon a well-planned public transport network that is supplemented by third-party services. Regulations and conditions conducive to collaboration and partnerships facilitate integration and serve as a platform upon which technology may play its role in enhancing the customer experience.

The nine-point innovation plan presented in this chapter should be consulted with the MaaS reform options and roadmaps set out in Chapter 7. The innovations are ordered according to priority (as were the MaaS options) and show how upstream measures form a foundation upon which downstream measures can build on. Each innovation consists of a number of steps and is accompanied by a discussion on a suggested implementation pathway, including commentary on associated risks and challenges.

8.1. Establish a systematic and embedded public transport network review process

The aim of a root-and-branch review is to 'design out' first/last mile accessibility issues as much as possible. The objective is to align the strategic layer, encompassing government policy such as *Victoria's Bus Plan* (Department of Transport, 2021), with tactical-level network planning outcomes. The importance of this exercise is to break path dependencies that have long plagued which suburbs enjoy better service—and seemingly questionable service level (and coverage) inconsistencies that seem inexplicable and misaligned with government policy. The review can be a zero-cost exercise (although it is well known that the bus sector has traditionally been underfunded in Victoria) by reallocating resources and streamlining services so as to ensure that each unit of service delivers maximum benefit to the community.

A root-and-branch review should, by definition, be comprehensive, systematic, embedded, and network-wide. This report has already embarked on a preliminary series of accessibility analyses that identified case study priorities for reform (Rowville and Cranbourne East, in particular). The complete components of this innovation include:

a) Commence a comprehensive analysis of public transport accessibility

Building on the accessibility modelling undertaken in this report (as a template [25]), a comprehensive analysis of public transport availability should be undertaken across metropolitan Melbourne to map the current level of service offering. The supply-side view can then be overlayed upon a demand-side population layer. As identified in government policy (Victorian Government, 2006), this should be overlayed with minimum accessibility standards (i.e., 90% of households within 400 metres of a public transport stop or station).

Examining intrinsic accessibility and land use indicators represents a first-principles, blank-slate approach to network development, rather than looking at service performance in isolation. The weakness in the latter is that present route structures inevitably shape performance and service levels (i.e., poor service leads to poor performance), and hence offers a skewed view in terms of informing service improvement, with insights likely to be a band-aid solution rather than an upstream fix.

Sensitivity analysis could then be undertaken for different networks (e.g., weekday, Saturday, Sunday) and times of day (AM peak, inter-peak, PM peak, evening) to capture temporal nuances in how accessibility differs. Cluster analysis can be undertaken to help rank areas where accessibility is low, with the results used as a baseline for prioritising reform of the public transport network.

b) Identify external catalysts for network reform

The Victorian Auditor-General's Office (VAGO, 2021) identified that network planning reforms rarely accompanied big-ticket infrastructure projects. Incorporating new bus networks as part of Big Build projects (e.g., the level crossing removal program) can better unlock the value of such infrastructure investments. The construction of new rights-of-way, new station interchange designs and significant alterations in traffic congestion levels present themselves as opportunities for implementing new bus network structures that can enhance local connectivity and mount a case for reforming networks (already besieged by disruption) that have been untouched for decades.

Communities suffering from poor service performance (punctuality/reliability) and subject to high levels of customer complaints or media attention may also be prioritised for network enhancements. Plans should further be developed for how future Big Build projects (e.g., new station hubs associated with the Airport Rail Link and Suburban Rail Loop) may allow the opportunity to rationalise routes and redeploy services to better feed new railway lines and serve an evolving urban form.

Risk: The community may confound network reforms with external developments. This occurred in Adelaide, where a new network was planned to be implemented with the entrance of a new bus operator as part of a contract retender. Community backlash and the association of the tender process with service rationalisations meant that the new network had to be ultimately cancelled. Conversely, in Singapore, the Bus Contracting Model (BCM), based on an open tender of a previously negotiated package of routes (Goh and Swee, 2017), was associated in terms of public messaging with the Bus Service Enhancement Program (BSEP)—even though under the gross-cost model where the authority designs the network, there is no association between the procurement of services with network design and the service quantity setting. However, the argument was made

[25] The methodology adopted in this report based on *Transport for London*'s Public Transport Accessibility Level (PTAL) is a useful *first* view on the accessibility landscape. Improving network structure is an important outcome but not the sole focus in this report. This report cross-referenced selected case studies with other data sources to provide breadth in how better integration and a MaaS proposition could be implemented. It is recommended that this proven methodology be adapted with outputs structured in a way to inform a wholescale network review.

that the savings associated with contracting out could be redeployed as part of new services to benefit the community (a form of hypothecation of revenue that can often garner genuine community support).

c) Establish a multicriteria ranking to prioritise reform implementation

Stakeholder engagement revealed that Melbourne's bus network reform is ad hoc and not systematic. Whilst new networks have been implemented in Brimbank (2014), Wyndham (2015), the Plenty Valley (2016 and 2019) and Cranbourne (2019), most other areas of Melbourne have not received a thorough review for decades. The result is many routes/service levels that no longer meet community expectations (examples in Section 6.4) and have not kept up with population density and distribution changes.

A needs-based approach that considers a number of criteria and practical readiness is required to establish a ranking of communities and timeframes for the reform of their bus networks. This list should be apolitical and published where possible to maximise transparency. Too often, local members of parliament are observed to meddle in the location of bus stops, schedules or route designs. Politicians should establish the outcomes (e.g., higher overall accessibility), but the means/processes to which this is achieved in terms of tactical network design and service level settings should be independent and developed without hindrance by domain experts.

The government could establish tiered levels of network/schedule reviews and timetable expected changes as an accountability and expectations management exercise. Tweaks to running times can take place multiple times a year, while minor route changes can occur once or twice a year (which do not require a complete set of shifts to be reproduced). Full-scale network changes could be scheduled every 3-5 years (as an example) and more often on the metropolitan fringe experiencing rapid development.

d) Work in partnership with transport operators and community stakeholders to deliver a network reform implementation plan

Once an ongoing (e.g., 5 year) plan of reforms has been established, relevant stakeholders should be identified and aligned as part of the network reform delivery process—starting as early as possible. This is particularly pertinent for stakeholders who have generally not been involved in the network design co-creation process (instead, being merely 'consulted' after plans have already been formalised), such as local government authorities and property developers (see Innovation 4.d). Early and frequent engagement can ensure appropriate road network layouts conducive to public transport are built and optimise the placement of bus stop infrastructure, which maximises coverage and walkability into communities. Starting the work early can bring a "decide-and-provide" approach to future transport and land use development decisions.

This partnership approach should also extend to bus operators to alleviate some of the concerns identified in the stakeholder ideation. Government should welcome operator initiative and provide a genuine equal platform for network development and implementation. A transparent evaluation framework should be established which recognises risk-taking for operator-initiated proposals, coupled with appropriate record-keeping ensuring that relationships transcend individual personnel. Opportunities to co-design processes and data gathering exercises to ensure that both parties have "skin in the game", take mutual responsibility, and are sufficiently invested in success are key.

8.2. Align public transport service levels with the established service hierarchy tiers

This innovation pertains to the operationalisation of network reform, complementing Innovation 1, which focused on systematically identifying the areas for reform. This study found significant inconsistencies in service level settings across communities and an absence of a transparent decision-making process, as well as poor alignment to the government's own policies in terms of how service levels are set. Elements of path dependency (with network principles dependent on the era of the network's establishment) and even influence by the individuals/teams involved in the network design process were found to affect network planning outcomes significantly. A more systematic and transparent approach to setting public transport service levels is proposed to maintain social equity.

a) Define frequency and span requirements at each hierarchy tier level
Victoria's Bus Plan (Department of Transport, 2021) provides a hierarchy of service types. However, key operating parameters such as service frequency and span at each hierarchy tier have not been prescribed. It is necessary to accompany the service tier framework with service level details as part of the implementation of the *Bus Plan*, in a way that is suitable for a metropolitan Melbourne context, but also cognisant of the necessary service level requirements for routes to perform their intended function (e.g., be frequent enough to encourage non-timetabled walk-ups for a turn-up-and-go service). For a low-density setting, the Ontario Ministry of Transportation (2012) provides a valuable set of guidelines for service type definitions which range from a bus every 5 minutes for very frequent service to every 20-30 minutes for a basic level of service. Specific definitions like this for the Category 1, 2 and 3 (Rapid, Connector and Local) routes in the *Bus Plan* should be developed as an urgent priority.
b) Allocate routes and cross-check service levels in line with stated policies
All routes must be explicitly allocated to a tiered level within the *Victoria's Bus Plan* (Department of Transport, 2021) hierarchy. The designation of a route should be related to its function and land use parameters, such as dwelling density. Again, the Ontario Ministry of Transportation (2012) provides an overview of minimum population/employment density requirements to support each service type (see Appendix A14). This provides a baseline setting for recommending actions where service levels exceed specifications (e.g., upgrading the designation or streamlining service), as well as instances where service levels do not currently meet assigned specifications.
c) Ensure service level definitions are applied consistently across different communities
It is imperative that the designation of routes amongst the service type hierarchy is consistent and based on objective truths such as the route's function and urban environment characteristics. This is particularly the case in suburbs that are entirely dependent on the bus or exhibit very similar patterns of public transport user behaviour (e.g., by being part of the commuter belt). A significant finding in this report is that similar metropolitan fringe communities in different parts of Melbourne exhibit the application of very different network design principles (manifested in the coverage/frequency trade-off and average stop distances). Service levels need to be applied consistently across similar locales, considering geographic and demographic determinants.
d) Ensure greater rigour in the application of service specifications and coordination requirements
Under the current regime, the Department of Transport establishes for bus operators service specifications which indicate the required level of service for each time-of-day period (e.g., AM peak, inter-peak, PM peak). Operators are then responsible for developing service plans and schedules which meet these particular requirements. The in-depth case studies in this report and investigation of timetables showed creative adherence where the 'letter' of the service

specifications were met but not the 'intent' of the service specifications. For example, services could exceed frequency requirements early in the AM peak but leave significant gaps in service later in the peak (despite average frequency requirements being met). Service specifications also establish other criteria, such as coordination requirements between bus and train (including in what direction and priority, segmented by the time of day). These requirements are essential but can also be seen as heavily prescriptive and rigid. There is limited attention paid to experienced service levels and local nuance—including that interchange distances (and hence the transfer time required) differ between stations and that train punctuality is poorer in the PM peak. New ways of measuring and capturing customers' actual interchange wait time (including via Myki data) and ways to restructure key performance indicators could be investigated and piloted (linked to Innovations 8 and 9).
e) Make publicly available datasets showing how each community meets service level requirements
As an accountability booster, datasets could be provided on how different networks meet service level requirements in each community, including adherence to government policies on coverage and service specifications around frequency and span (linked to tiered levels in the *Bus Plan*), as well as coordination requirements. This could be similar to how private operators are held to account by publishing on-time running data and providing a dual mechanism that nurtures trust and ensures that like-for-like communities receive comparable public transport service levels. Clear and transparent communications also build support for disruption and change. Regular audits of service levels can maintain equity and service accessibility in line with land use and population changes. Implementing Innovations 1 and 2 in full establishes Victoria as a national leader in values-driven network planning, ensures transparency and depoliticises often controversial public transport planning decisions.

8.3. Lead greenfield service with DRT; mature with fixed route

Poor agility of the fixed-route bus network was a recurring theme in this study. Once implemented, routes and timetables (and stop location) are notoriously difficult to alter. There is often little political will to accept disruption and change, particularly where some people may be disadvantaged, despite many more people potentially benefiting. In new developments on the urban periphery, fixed-route bus services are often implemented many years after new residents move in, leading to vast public transport deserts and the early onset of automobile dependency.

There is scope to consider a more agile way to implement some level of service commensurate with demand as an area grows. Demand-responsive transport (DRT) is not a go-to solution suitable for all settings, but it is incredibly versatile and ideal for rapidly developing communities where demand is thin or undergoing rapid change. Notably, operating DRT can serve as an ideal data gathering exercise to better understand travel patterns, particularly in getting an accurate picture of points of origin and destination (at the household, rather than the nearest bus stop, as is traditionally the case with smartcard ticketing data). This can assist in the design and development of a permanent fixed-route bus offering.

a) Assign a standby DRT technology provider for each growth centre
Currently, there is no overarching strategy for the deployment of DRT—either relating to demand characteristics or land use. Designating appropriate settings for DRT deployment such as serving the rapidly growing urban periphery can provide both demand-side certainties (for residents moving in), as well as send a supply-side signal to the market, including amongst DRT technology providers, asset owners and service deliverers (including supporting business planning and depot space management). Through an open tender (or otherwise), the government can appoint a standby DRT technology provider to service new growth centres. Different providers may be appointed for the western, northern, and southeastern growth centres to ensure adequate competition. Each technology provider may be allocated to (or their selection led by) a lead bus operator (e.g., CDC Victoria, Dyson, Ventura, Cranbourne Transit) to provide crew, maintenance, and other support services for operating the DRT service. **Risk:** Vendor lock-in is a real risk, and a balance needs to be sought between the fragmentation of solutions providers and excessive centralisation. Queensland is an example where there is one single government-appointed DRT technology provider. Whilst this can offer a better integration experience and reduce transition/transaction costs as well as generate cost savings through the ability to reap economies of scale, it can also lead to the risk of single-vendor lock-in and the inability to benefit from innovations brought to market by competing operators (especially relevant given the rapid pace of technological change).

b) Develop a database of underutilised community vehicle assets and service capabilities
Having appointed a technology provider and identified available personnel resources (via a partnership with a lead bus operator), it is then necessary to consider the vehicle requirements for running services. New vehicles may be purchased, and this is suitable for long term DRT programs, including supporting redeployment across different growth areas as DRT service requirements vary. However, this can sometimes be constrained due to financial limitations, as well as require longer lead times for implementation. A major finding in this study related to how local government and community transport vehicles were currently underutilised. Many community transport shuttles operate bespoke services such as transporting seniors to local shopping centres during the day but remain idle at other (including peak) times. There exists the opportunity to improve the temporal utilisation of these vehicles to provide public transport services, and their generally smaller size (mini- and midi-buses) make them ideal as DRT vehicles. Bespoke community transport services may also be brought under the auspices of a MaaS ecosystem (in the same way as new mobility modes discussed in this report). WYNBUS served as an example of a community enterprise that developed from the ground up to serve Point Cook and shows how underutilised assets which belong to council or community transport groups may be repurposed for open-access public transport services, benefitting all stakeholders. A catalogue of available local assets should be developed in partnership with local governments (e.g., Wyndham, Brimbank, Hume, Casey) and kept in a shared government database. Consideration of the vehicles' period of availability, technology fit-out and disability compliance should be made. As vehicles are required for DRT, appropriate underutilised assets and service capabilities may then be leveraged to provide services within relatively short implementation timeframes.

c) Implement DRT services as new residents move in (within weeks)
The means of operating DRT should complement comprehensive public transport service provision plans for new communities (often, there is a myopic focus on road infrastructure and level of service, but not enough regard for public transport). As residents move in and population thresholds are met, this should trigger specific levels of DRT service. The provision of public transport should be enshrined in specific terms as part of agreements with property developers. Financial support, including through developer contributions (see Innovation 4.d), could be used to cover set-up and operating costs. A heavy focus on marketing and communications should then be made to increase awareness of the new service to residents. The DRT service should integrate with public transport in terms of information provision and multimodal fare products as much as possible (the focus of Innovations 5-7).
d) Ensure active monitoring of service performance and travel behaviour
The active monitoring of service performance is critical and relies on the provision of datasets and business information interfaces by the service provider (usually the technology platform solution). Real-time monitoring is required for operational management and to adjust the service (including medium-term decisions such as the number of vehicles and drivers) in response to demand in order to maintain service levels (meeting maximum wait time benchmarks, for instance). The dashboard interface should also provide longer-term travel behaviour trends and key metrics such as cost per trip and passengers per service hour.
e) Mature services with a fixed route bus offering (within years) and scale assets to new growth areas
One of the issues of DRT is its limited scalability. DRT only works until it is successful, after which wait times and costs may blow out. As patronage increases, the flexibility of DRT should be constrained, with the service taking on a more rigid form to maintain minimum service levels and to control costs. For example, this could mean replacing door-to-door journeys with fewer virtual bus stop pick up points. Where demand warrants, or when a cost benchmark has being breached, the DRT should be replaced by a fixed route bus service. This should be informed by the demand patterns exhibited on the DRT service. Managing stakeholder expectations is particularly challenging where there is uncertainty associated with a DRT service not being permanent. The service level agreement with the community should be based on mobility/accessibility rather than particular formats of service.

8.4. Scale new mobility modes, whilst maintaining equity

A range of new mobility modes such as ridehailing, carsharing, microtransit and micromobility have come online in Melbourne. These services are generally commercially operated and governed within a regulatory framework that emphasises safety and compliance rather than the equity of service coverage. As a result, some areas of Melbourne enjoy abundant services, whilst others are not serviced (or serviced poorly) by these new mobility modes.

New models of service provision (including the blurring of commercial and contracted microtransit) and the emergence of new vehicle format types also mean that the current regulatory framework is inadequate. Providers of these new services often seek clarity on entry-to-market or seek government support for trials and regulatory reforms (so as not to operate outside existing rules and regulations). The government should provide a straightforward approach avenue for private sector proponents and establish a consistent framework for undertaking trials that maintain a level playing field for new technologies and business models. Finally, the government can use the levers of permits, fees and subsidies to nudge entry into markets (such as outer suburbs) which maximises the benefits of new mobility modes for the community.

a) Establish an easy approach avenue for private sector operators and technology providers to engage with the government
The stakeholder engagement exercise identified that private sector liaison with the government was often ad hoc and based on personal connections. Solicitation can be more structured with the establishment of defined channels to approach the government. This is rarely aimed at obtaining financial support, unlike market-led proposals which focus on big-ticket infrastructure projects. Private sector proponents often seek to test potential government support for regulatory change (such as reforms relating to micromobility) or to ascertain the ability of the government to share crucial datasets (so as to be able to develop third-party digital offerings, for instance). There is a need to balance welcoming private sector initiative and new proponents' willingness to engage with the government maintaining probity, disclosure requirements and protecting against regulatory capture. Open government programs such as problem-focused innovation challenges (without the government being prescriptive on a solution) can be a novel way of encouraging genuine collaboration between public- and private-sector enterprises. The trial of new mobility technologies and services can be one promising application of such programs.
b) Develop a template to design, implement and evaluate trial services
The implementation pathway for new trial services is not standardised nor transparent—especially relevant where they are dependent on government approval or financial support. This can make decision-making prone to political interference as well as undermine trust and confidence from the private sector. The government must ensure appropriate balance in terms of the selection of partners and the design of trial service offerings. There are characteristics of technologies and service offerings that might warrant different pathways to implementation. Sometimes, an exclusive negotiation is warranted where significant intellectual property exists and can hence offer better value for money than via a competitive tender or where the government delivers the service itself. Information asymmetry between the public and private sectors can be highly challenging and hence require extreme due diligence. It is also often the case that new mobility modes are being designed and implemented outside of the arena of government (beyond safety regulations) and driven by private profit without regard to how they complement the transport network, including potential adverse consequences (e.g., traffic congestion or displacing public transport trips). Government can play a role in 'nudging' the selection of trial sites to ensure they deliver the greatest benefit for the community. This can even be one metric for determining the right to operate or a condition to receive particular government supports. The designation of *regulatory sandboxes* could also be used as a framework to test modes/technologies which exist beyond present regulatory arrangements. It is recommended that the Department establishes a trial implementation framework specifying risk allocation, funding source, and revenue split, including setting criteria for evaluating a trial's success (or otherwise). This should be complemented by ex-ante and ex-post behavioural and longitudinal studies, coupled with wide knowledge sharing (preferably whole-of-government and beyond state borders).
c) Encourage new modal offerings on the metropolitan fringe
Inner suburbs can often be saturated with new modal offerings, which inundate local roads and limits the productivity of each vehicle due to an oversupply of services. Whilst the result is more choices for the consumer, this can whittle away private profits, as well as exacerbate inequalities in access to transport between the inner and outer suburbs. Hotelling's law of minimum differentiation (Hotelling, 1990) provides a theoretical basis for why in a free market scenario,

individual agents (private-sector operators acting independently) tend to converge and compete in the same, overlapping areas.

The government can, therefore, take the lead to delineate operating areas and help spread service provision to thin markets like the metropolitan fringe and middle suburbs. Permit fees and other charges (see Innovation 4.e) could be designed in a way that accounts for likely differences in operating margin between various markets. Regulatory, legal and financial instruments can be a critical enabler for maximising the benefits that new mobility modes bring to the community.

d) Review and channel developer contributions

The interdependency between land use and travel mode choice is well established (Cervero and Kockelman, 1997, Ewing and Cervero, 2010), and this is particularly pertinent in greenfield developments where a significant opportunity exists to shape travel behaviour. Building communities with excellent access to services and facilities and designing developments conducive to public transport and active mobility requires coordination from the earliest upstream intervenable point. Developer contributions have been one primary way some portion of private windfall gains may be redirected to local and state governments to support the provision of community infrastructure and services.

Programs such as the Growth Areas Infrastructure Contribution, Developer Contributions Plans, Infrastructure Contributions Plans, as well as via (as a legal instrument) voluntary agreements, can channel funds to support public transport services and new mobility trials. Various criticisms have been made of existing programs that enable developer contributions to be deferred, especially for major projects such as bridges and thereby causing 'missing links' which prevent public transport from cost-effectively running. The funding of bus services that are rigidly tied to growth areas can result in a suboptimal network (with inefficient overlaps or missing critical links), as well as pose continuity issues for when the funding source is eventually exhausted. The Victorian Auditor-General's Office (VAGO, 2020) further provided recommendations to reform the existing fragmented approach to collecting developer contributions across a mixture of programs and proposing how contributions may be situated within a framework better aligned to overall strategy and vision.

New opportunities exist for developer contributions to be provided in more fluid ways, including to support new mobility modes. The provision of demand-side subsidies paid to residents via voucher programs can support travel on sustainable modes of shared mobility. As an example, residents can receive discounted carsharing options or even credits on their ridehailing account as part of a bundled rental package. Such innovative offerings have been explored in developments in London and Phoenix, Arizona (US), to support the creation of car-lite neighbourhoods and to provide an alternative for developers who can then be exempt from meeting (as an example) minimum parking requirements. Developer contributions may also be channelled towards supporting the trial of new mobility modes and technologies; notably, the development may be constructed in a way to enable the trial or to safeguard its success (such as providing sufficient right-of-way for e-scooters, for instance). These innovative opportunities represent a blurring of sector boundaries between property developers and transport operators, a trend likely to proliferate in the future.

e) Consider the role of public subsidises in supporting equity in the deployment of new mobility modes

Reviewing the current regulatory approach for new mobility modes (linked to Innovation 5.a) is vital for ensuring a level playing field. One of the key considerations relates to the design of permit fees which at present are a blunt instrument not consistent with desires to improve transport equity, such as supporting the expansion of new mobility modes into thinner markets on the metropolitan

fringe. The flat $1.05 per trip Commercial Passenger Vehicle Service Levy[26] charged for each ridehailing trip, for instance, discourages short distance ridehailing trips, including those used for first/last mile travel to public transport. The way this charge is levied for commercial microtransit (such as UberPool) but not for contracted microtransit (such as for the TeleBus DRT, which is classified under the bus sector) is inequitable for services that seek to serve the same function. One way in which permit fees can support service provision is by adopting a tiered approach as Auckland applies to micromobility permit fees. Fees charged to commercial operators further from the CBD are lower to take into account different demand characteristics. The design of even 'negative' permit fees (i.e., subsidises) can further help support the expansion of new mobility modes from lucrative to thinner markets. This requires the Department to work more closely with local government authorities responsible for regulating micromobility. Cross-subsidisation is a fundamental concept in public transport provision. Lucrative shuttle services (e.g., university bus shuttles) and trunk lines to the CBD are used to support low patronage services, which play a coverage function and provide an essential lifeline to communities. The same principle may be extended into the realm of new mobility modes to support equitable service provision. This is linked to a wholescale reform of the way transport services are procured and funded, examined in Innovation 9.

8.5. *Develop a trust architecture and data sharing repository to facilitate TNC integration*

The governance of new mobility modes such as ridehailing, carsharing, microtransit and micromobility is highly fragmented and inconsistent. The nature of market entry by private operators and whether they predated or followed legislation/regulation shapes the procurement process and requirements around permit fees, enforcement, the provision of data, and their incentive to cooperate with other modes/operators. This is complicated by modes managed by different government levels (state and local) and jurisdictional boundaries between local government areas. Better consistency applied across TNC modes can nurture a more level playing field and is essential to facilitating multimodal experiences and MaaS, which brings together as many modes and operators as possible.

a) Review the regulations governing each new mobility mode and their right to operate
The current fragmented approach to governing new mobility modes is highly dependent on the context of TNCs' entry into the market. The right to operate can vary from free-market entry (competition *in* the market) to a controlled environment based on permit applications (competition *for* the market). The designation of permit fees (see Innovation 4.e), data sharing requirements, and responsible level of government/agency is not well linked to overarching transport strategies and objectives. This is particularly true where services that perform the same function are governed differently depending on who is providing the service. Microtransit is one such example where requirements and fees vary depending on whether services are contracted (supported by government and led by bus operators) or commercial (operating from the farebox by TNCs). The regulatory differences between each mode must be rationalised, and a wholescale strategy for governing new mobility modes must be established (linked to Innovation 8.a). Only then can a level playing field be facilitated that supports a market outcome (rather than one distorted by inefficient

[26] This levy was established in July 2018 with funds collected by the State Revenue Office to fund an industry transition fund.

legislation), helps expand service provision, whilst supporting TNC integration and the development of MaaS.

b) Establish a comprehensive data-sharing framework for the TNC sector

Compelling third-party providers to share data and participate in an aggregation platform can be a real challenge. Evidence shows that smaller operators are keen to engage since this brings greater exposure to the market, whilst larger operators are incentivised to maintain their 'walled gardens' given they are already the market leader and do not derive benefit from sharing their status with smaller competitors. Several MaaS Lite examples in Australia show that larger TNCs may be willing to cooperate only where they can continue to "own the customer"—in effect becoming a broker themselves (Innovation 7). Otherwise, direct government intervention, such as multihoming requirements in Singapore, is required to compel data sharing and multihoming as part of TNCs' rights to operate.

The current patchwork of TNC regulations means that data sharing is only required for some new mobility modes. Data sharing (e.g., via MDS or GBFS) is a prerequisite for micromobility permits under contract to local government, but the sharing of vehicle availability and ride data in the ridehailing sector (regulated by the state government) is a virtually unheard of phenomenon. In fact, Uber's former *greyballing* activities even meant that false data was being shared with the government when officials sought to undertake compliance-related enforcement activities (Larcker and Tayan, 2017). The provision of quality datasets is not only a critical compliance enabler (in the spirit of the *trust, then verify* approach to monitoring the sector) but also crucial for enabling multimodal journey planning, real-time customer experiences and integrated ticketing products.

All TNC services use public assets and so should be subject to similar data-sharing requirements. However, it is recognised that operators compete *in* the market (unlike for contracted public transport operators), and so the data shared should be cognisant of not compromising commercial interests. A TNC data framework should be developed that stipulates the data items, level of aggregation, formats/specifications, and frequency of updates to enable compliance monitoring as well as delivering integrated multimodal experiences for customers.

c) Appoint a data custodian as an aggregator and intermediary

A data-sharing framework establishes datasets that must be shared, but these raw files require processing to generate insights and to enable interoperability. An established entity must manage the data's collection, sharing and storage. It is especially vital that the data is anonymised, privacy safeguarded and that sharing only occurs with legitimate users—all based on the local Victorian legal framework.

This data custodianship may be undertaken in-house within the government or entrusted to a third party under contract to the government. Even if kept in-house, it is recommended that a specialist, off-the-shelf technology is procured under a white-labelled software-as-a-service model—to minimise risks to government and to maximise product reliability. The establishment of a third-party data custodian can help keep more sensitive raw datasets at arm's length from the government. Such a layer of protection may be preferred to help build trust and to achieve buy-in from third-party transport operators.

These processed data feeds on the data hub can then be used by both government and third parties to aggregate and provide integrated multimodal and journey planning experiences (including in the PTV journey planner). These opportunities are further explored in Innovations 6 and 7.

d) **Implement new regulatory requirements, ensuring the consistency of application across each new mobility mode**
Regulatory requirements should be consistent across operators and modes as a general principle. Taking a whole-of-sector approach that begins with this overarching objective is critical. Whilst the government must maintain its vision and firm approach, liaison and market testing with industry stakeholders is also essential. Regulations must balance private risk and reward and not be overly onerous so as to drive out operators. The Department can look to more mature markets around the world—Los Angeles is an oft-cited best practice example with the MDS specification requirements for micromobility, for instance. Implementing new regulatory requirements can be particularly challenging when they are introduced to a sector that has to date been under-regulated (e.g., ridehailing). One possibility is to triage new requirements (including which datasets are shared) and specify those which are voluntary and mandatory. Sweeteners such as expanded rights to operate and eligibility for behavioural incentives (see Innovation 8.c) could be available for TNCs which go beyond minimum regulatory requirements.

8.6. Determine the government's role in the MaaS ecosystem

Having set up a trust architecture framework and data sharing repository as critical enablers of MaaS, a mechanism must then be established to bring together disparate service providers and to provide an integrated service offering for customers. Known as the MaaS broker/aggregator, this entity provides the one-stop digital MaaS platform and takes custodianship of the customer engagement interface.

Different schools of thought exist for the government's role in a MaaS ecosystem, including their suitability for performing the integrative MaaS broker/aggregator function. In Victoria, the government has not yet determined its position in the MaaS ecosystem. As the procurer of public transport services and transport network asset owner, the government is well placed to take on the role of the MaaS broker/aggregator. The government already is the primary digital customer interface for public transport services, but not new mobility modes. By expanding its responsibilities and taking on the custodianship of the MaaS ecosystem, the government can maintain its interface with customers whilst reducing the risk of variations in digital experience.

a) **Market test which operators are willing to participate in a government-led MaaS ecosystem**
As identified in the stakeholder ideation, one of the difficulties of a government-led MaaS broker is that it may cause reluctance amongst private-sector TNCs to join the ecosystem. Perceptions of bias, concerns about political interference and the breaking of the 'veil' between regulator and operator in an economically deregulated operating context can be key challenges. A market sounding exercise is therefore required to identify which modes and operators might be willing to participate in a government-led MaaS program, as well as understanding to what extent this might be dependent on the level of MaaS integration being proposed. The results of this market test determine whether a government-led broker model can be feasible. If enough new mobility modes are able to participate, this brings sufficient value working in conjunction with public transport services to provided integrated mobility services for customers. Any reluctance may mean that these TNCs need to exist outside of the MaaS ecosystem. Additional regulation (linked to Innovation 5) may be required to mandate their participation, or in the alternative, it might be deemed that the government is better placed to nurture an ecosystem where third-party MaaS platforms are able to prosper (Innovation 7).

b) Build deep link and native integration capabilities in the PTV application

The centrepiece of a government-led MaaS offering is the digital interface that provides customers information, booking, and payments options. Rather than starting from scratch with developing a new MaaS platform, additional capabilities may be added to the existing PTV application.

As a public transport journey planner at its core, the challenge is to bring in datasets and feeds that currently reside with TNCs in the private sector. Extending the journey planner to incorporate new mobility modes is more easily achieved on a deep link basis where customers may be sent to third-party applications with required information fields pre-filled (such as origins and destinations). Deep-linking, whilst more readily achievable, can make it challenging to provide seamless multimodal integration, such as real-time experiences and payments integration. Critical constraints (including vendor lock-in with the current provider of the PTV application backend) and how well the solution may work in practice must be further investigated in conjunction with software developers and third parties.

A native integration approach provides bi-directional information flows to and from third-party operators. Native integration can allow customers to view live vehicle status and make bookings for TNC services directly within the PTV application. Native integration can provide a full MaaS experience but requires substantial cooperation (and investment) from the third-party provider, including the publication of application programming interfaces (APIs) and operational datasets. These private operators must also determine whether they choose only to offer services via the PTV application or intend to continue offering services independently via their existing customer engagement channels (which they would have already invested heavily in building). This is likely to be a significant point of contention, and direct competition (or predatory pricing) can ultimately undermine the success of the government MaaS offering.

c) Establish Myki as a multimodal digital wallet

The integration of payments and provision of subscription packages represent higher levels of MaaS integration. With public transport at its core and the PTV application used as a mechanism for delivering government-led MaaS, the Myki ticketing system lends itself well for use as a digital wallet to also provide payment functionalities to TNC-provided modes such as ridehailing, carsharing, microtransit and micromobility. Similar smartcard systems in other international jurisdictions can already be used for payment on private modes and retail settings. In Sydney, the Opal Connect ecosystem allows the Opal card to be used on DRT, which exist outside of the public transport fare structure (customers also receive a $2 transfer discount when connecting to and from public transport). The Opal digital card even enables customers to use the near-field communications (NFC) functionalities on their smartphone or smartwatch to make the payment, in the same way that contactless bankcards may also be used as an Opal substitute on Sydney public transport.

The design, development and deployment of a digital Myki payments experience enable payments integration between public transport and new mobility modes. In the longer term, the democratisation of payment mechanisms beyond vendor-specific solutions can further support the development of MaaS packages that transcend traditionally siloed modes and operators.

Whilst delivering an interoperable payments mechanism is a technological requirement for implementing Level 3 MaaS (Sochor et al., 2018), the provision of multimodal packages which are truly attractive to customers is conditional on innovative financial agreements between service providers and the MaaS broker/aggregator. The wholesale price at which TNCs sell service capacity to the MaaS broker for customers to consume through the PTV application determines the types of bundles that are able to be offered. Revenue sharing arrangements need to be established to protect the interests of third-party operators and ensure that customers find value in consuming services via a MaaS interface. Subscription bundles should also be designed to attract sustainable travel behaviour, such as by leveraging micro-subsidies as envisaged in Innovation 8.c. Higher-level MaaS, which incorporates the provision of subscription bundles, can be more complex to implement but has the potential to bring about the most significant benefits for solving the first/last mile and supporting transport network efficiency.

8.7. Support the establishment of third-party MaaS ecosystems

A major impetus for government intervention is to solve instances of market failure. While the government can take the lead in acting as the MaaS broker/aggregator, it is difficult to argue that this is required only because the private sector has failed to deliver. There can be a misguided belief that the authority must maintain and expand its in-house digital transport capabilities (and often at significant expense). A common approach in many jurisdictions is for the government to step back by becoming a data provider and enabler of third-party MaaS integrators. In this setting, the best of private-sector innovation may be leveraged, providing flexibility and allowing the government to return to its core functions, such as playing an independent 'umpire' role to maintain a level playing field. The government can take steps to allow public transport datasets to feed into third-party aggregators, supporting an open MaaS ecosystem and guarding against a fragmented alternative with many 'walled garden' individual bilateral relationships.

a) Establish a catalogue of government-held data feeds, service level agreements and fees

Presently, the Department lacks an overarching data management and sharing strategy. Whilst open data access is a stated policy, the way this is operationalised remains project-based and ad hoc. Specifications are not fully compiled nor defined. Even internal datasets are not centrally managed nor adequately catalogued.

One approach to engaging third-party stakeholders is by establishing contractual partnerships with interested private companies, where a payment is made for a guarantee of data services and 24/7 support services (complete with service level agreements). The Department can start by establishing a catalogue of services and fees which can be offered to all third parties so as not to negotiate with individual vendors. This type of consistency of approach can aid MaaS ecosystem formation and provide an important market signal that can assist third-party integrator positioning.

b) Provide open APIs to third party operators and integrators as government policy

The stakeholder interviews revealed that the way the Department engaged with private sector actors is inconsistent. Technology giants such as Google are able to gain access to public transport APIs by virtue of their larger market share, and are thereby able to provide added functionalities such as fare estimates and real-time vehicle tracking on their products. Smaller players (as described in RACV's *Arevo* case study) could not gain such access and thus resorted to workarounds such as screen-scraper technologies. With the public interest in mind, there is a strong case for the Department to treat all vendors equally, subject to a framework (including fees, where appropriate), as prescribed in Innovation 7.a.

Providing open APIs to all third-party operators and integrators reduces barriers to entry and ensures a level playing field. This guards against a "winner takes all" approach, supports home-grown alternatives to overseas technology giants, and ensures a more competitive MaaS ecosystem. Importantly, an open approach to dataset provision can discourage bilateral agreements and 'walled gardens' from emerging and support the development of an open MaaS ecosystem characterised by many-to-many relationships between operators, vendors and integrators.

c) Enable the third-party resale of Myki tickets
One of the key requirements for enabling a third-party MaaS ecosystem is that private MaaS providers must be able to sell public transport tickets that traditionally have been in the realm of the government and their contracted ticketing provider. In Melbourne's case, the Myki system must therefore be made compatible with third-party MaaS platforms. This could be undertaken in a variety of ways ranging from low to high technological complexity. However, all rely on public transport tickets no longer distributed solely via existing (government-controlled or contracted) channels but also through third parties (i.e., private-sector MaaS brokers). Whilst third-party resale can be purely transactional in terms of offering the same public transport fares and ticketing products (thereby enabling PAYG MaaS), the real potential comes from new financial arrangements that enable integrated subscription packages to be offered to customers. This requires the public transport capacity to be sold at a wholesale price from the government to the MaaS broker, similar to private-sector TNCs' relationship with the government in the case of Innovation 6.c. Again, the interests of both the service provider and the MaaS integrator must be maintained, and subscription products offered to customers sufficiently competitive/attractive over consuming the services directly in their non-bundled form.
d) Enable mobile ticketing on public transport
Where there is a divergence from Innovation 6.c, however, is the payment mechanism itself. Unlike with new mobility modes, which rely entirely on mobile ticketing, public transport in Melbourne continues to be based on a physical smartcard token and gate infrastructure, which forms (at gated stations) a physical barrier for travel on public transport. Even if customers are able to purchase access to public transport digitally, they may be physically unable to use the system without a cumbersome reliance on the Myki smartcard. As a workaround, the ODIN PASS MaaS trial in Queensland includes a flash pass within the application which can be used to present to drivers and station staff, exempting them from touch on and touch off requirements. However, this suboptimal solution reduces the efficacy of existing data collection methods and opens the door to fare evasion. Added Myki gate infrastructure functionality that includes NFC capabilities can allow third-party MaaS solutions to better interface with public transport. In the longer term, as Myki is replaced by newer generations of payment systems, completely mobile ticketing solutions that no longer require validator infrastructure can be used to provide an even more seamless experience.

8.8. Review contractual regimes and funding frameworks

Traditionally, there has been a myopic focus on integrating specific modes in a physical sense, as opposed to considering the broader organisational, data integration, and even land-use factors, which are equally crucial for integration. Whilst the preceding innovations have covered aspects of physical network improvement, data sharing and digital requirements, issues of funding, governance and procurement have yet to be treated in detail. Upstream interventions that target the very essence in which transport is delivered can incentivise (or endogenise) multimodal integration, particularly between public transport and new mobility modes.

a) **Review the *Transport Integration Act 2010* with an explicit view to incorporate new mobility modes**
The Victorian Auditor-General's Office (VAGO, 2021) review revealed many shortcomings in the implementation of the *Transport Integration Act 2010*, including a continued siloed mentality to policymaking and how levels of responsibility and access to funding continued to vary significantly between and across different departments and levels of government. The Act itself has also failed to keep up with the pace of technological change, which means that the present transport landscape differs vastly from 2010—for instance, being more fragmented and democratised in terms of the influx of new mobility modes such as ridehailing, carsharing, microtransit and micromobility. A comprehensive review of the Act should help to ensure an outcomes-based approach that harmonises mode-specific differences in regulation with the aim to increase service supply, improve equity, and beyond this to promote integration and facilitate MaaS. Innovations 5, 6 and 7 underscored the importance of data sharing requirements, digital platforms and payments on this journey. Further reforms are needed to decouple certain elements (such as the link between specific payment mechanisms, modes and operators) which exist as constraints to help further support MaaS evolution. Finland is a case in point that has embarked on mode-agnostic reforms to bring together public transport and new mobility modes. The *Finnish Transport Code* provides for third-party resale of all ticketing products, as well as mandating open APIs for both public and private service providers so that they can be integrated into a single MaaS ecosystem. Such reforms can act as a template and north star for updates to the *Transport Integration Act 2010,* and in particular, ensure that its directives are not only aspirational but legally enforceable.
b) **Provide greater patronage incentive amongst existing mode-specific contracts**
Decades of institutional reform has moved the public transport sector towards a gross cost operating model, which has virtually eliminated the revenue risk of private sector operators but also the potential reward they are able to extract from attracting higher patronage. In the words of bus operators, they are now paid to “deliver kilometres” rather than to carry passengers. The centralisation of network planning functions by the Department has the potential to increase network integration (though other limitations prevent this from being realised fully, hence the need for Innovations 1 and 2), but also reduces the impetus for private innovation, including activities that target service access, such as collaboration/partnerships with TNC-provided services. Enhanced patronage incentives built within existing mode-specific contracts can alter this balance of risk and reward and drive greater initiatives that target first/last mile access. Whilst metropolitan train and tram contracts feature patronage growth targets and associated financial incentives, their specification in aggregate growth terms and link to overall mode share and population growth projections can be too blunt for operators to be compelled to invest in location-specific initiatives. Example programs could include marketing and communications initiatives, multimodal fare and ticketing products (enabled by Innovation 7) and deep partnerships, including with precinct-level travel managers and developers to provide a seamless travel/lifestyle experience. **Risk:** The COVID-19 pandemic has created unprecedented challenges for public transport patronage, including for Melbourne’s train and tram operators, who have had to resort to emergency funding mechanisms (management contracts) as an interim measure. Robustness must be built into contracting models to guard against black swan events whilst incentivising operator

initiative. Appropriate safeguards can be put in place on a *cost-plus* operating model basis which guarantees minimum operating costs can be covered but offers a substantial reward for operators who go above and beyond.

c) Explore user- and supply-side funding support to nudge sustainable travel behaviour

The current approach to operator remuneration (and even Innovation 8.b) is built directly into specific operating contracts and hence challenging to scale sector-wide. Financial incentives can also be directed to end-users, as well as providers of new mobility modes—especially in ways that are aligned with supporting sustainable travel behaviour (such as using TNC-provided services as a first/last mile option to access public transport). This goal is closely aligned to the design of MaaS subscription packages and the governance overlay in terms of the link to societal objectives; this differentiates Level 4 from Level 3 MaaS (Sochor et al., 2018).

However, given the focus on the commercial imperative, the market is unlikely to deliver MaaS subscription products that are necessarily aligned to government objectives. Rather, there is a real risk that third-party MaaS brokers might push customers from public transport to (potentially more lucrative) car-based modes like ridehailing. In other contexts, however, there could be a case of bundling services that are more expensive (and less sustainable) than a pure public transport solution but is effective in attracting users away from their private cars. Direct regulation (e.g., linked to the right to operate) and financial incentives (e.g., co-funding bundle discounts, in line with Innovation 4.e) directed at service providers can be used to support sustainable travel behaviour nudging.

The design of behavioural nudges and micro-incentives must be transparent, vendor-agnostic and systematic, as well as based on a suite of clearly defined objectives with specified rules and triggers. In the longer term, technologies should be adopted to manage, monitor and control such incentives, including their impact on ultimate travel behaviour outcomes (similar to Innovation 9.c). This requires the independent and real-time management of key performance indicators and data analytics capabilities that can granularly monitor and target individual users, trips and locales to maximise financial and societal goals. Notably, some comparison with the baseline (or counterfactual) should be used as a benchmark to evaluate whether the incentives have contributed to enhanced sustainability outcomes.

d) Encourage the development of multiservice MaaS propositions

A suite of opportunities exists to extend MaaS beyond the traditional realm of transport into related (and synergistic) sectors. Retail and property are two key sectors where the blurring of sector boundaries offer significant benefits and opportunities for both transport service providers and other private sector businesses. Retail and lifestyle partnerships have a long history in developed Asia, particularly in markets such as Japan, Korea and Greater China. Bilateral relationships between TNCs and local businesses have also emerged, particularly amongst ridehailing and micromobility operators. For instance, local businesses are able to partner with these TNCs to be featured within their applications, including providing targeted vouchers/discounts to drive footfall. In a MaaS ecosystem, retail partnerships can also be used to bring greater value to mobility packages, as well as to nudge travel behaviour. During service delays or in the event where demand significantly exceeds supply and minimum service levels cannot be met, retail incentives (as an example) can be used to smooth demand and maintain customer satisfaction.

As discussed in Innovation 4.d, MaaS integration with land use and property developments can help foster car-lite communities. Property developers can partner with MaaS integrators to provide customers with mobility credits, either independently or as part of rental agreements. The government can grant developers concessions in return for reducing private vehicle demand, by easing minimum parking provision requirements or by providing more scope to expand building heights. These synergies are often neglected in the discourse on future mobility and should feature more prominently in the planning and potential for future MaaS ecosystems.

8.9. Pilot mode-agnostic mobility contracts

Whilst Innovation 8 provided a series of steps to support higher-level MaaS largely within the existing procurement framework, only radical alternatives for procurement reform can truly endogenise multimodal integration. This involves moving from a traditional mode-specific, output-based approach to procuring transportation to one which is mode-agnostic or outcome-based. In this way, the government no longer "purchases kilometres" on defined routes and for defined vehicle types (e.g., buses) but instead takes a needs-based approach where the mobility custodian (or MaaS integrator) may be able to provide accessibility using any vehicle of their choosing (Wong et al., 2020). A new set of key performance indicators is required to ensure that the entrusted MaaS provider delivers a genuine multimodal travel experience and meets minimum service levels across defined geographic areas. This total mobility approach to procuring transport services via mode-agnostic mobility contracts is also consistent with the precautionary principle and is able to scale as new mobility modes/technologies come online in the future.

a) Develop a unit accessibility measure as an underlying key performance indicator

The level of service for new mobility modes should be defined in very different ways to traditional fixed-route public transport. In a mode-agnostic environment where public transport and TNCs work hand-in-hand, there is less need for rigid key performance indicators like on-time running, excess waiting time or headway regularity. Rather than service-specific measures, new measures of access can be defined, collected at the individual level and covering both users and non-users. This might be stipulated in (for instance) *X* proportion of residents receiving transport service within *Y* minutes, for *Z* hours of the day. This constitutes a radical shift from existing service level agreements with transport operators and requires new data analytics and real-time sharing capabilities.

b) Set a baseline requirement for minimum service levels and the parameters of operation

The MaaS provider needs to meet minimum service levels, which can vary across time and space—for instance, this can be lower in the evening than during peak periods and less stringent in lower demand settings than on trunk corridors. The MaaS provider must then be held accountable for *potential* service, as well as the *actual* service delivered. Additional top-up subsidies may be required to support a higher social safety net (measured in terms of accessibility) should a market outcome provide a service shortfall. These data items are more complex to gather, report, monitor, and enforce but essential in ensuring that MaaS is not a niche product for the few but a scalable proposition for the masses and a true alternative to private vehicle ownership.

c) Design a real-time framework to monitor experienced service levels

To meet the specified minimum service requirements, maintain an equity focus and ensure value-for-money for subsidies outlaid, a real-time framework must be developed to monitor the experienced service levels of MaaS customers. This means transcending the traditional focus on requirements such as (for example) on-time running, which is meaningless when no one is on board, to one more closely resembling a passenger-weighted measure of actual wait times for services. Once again, the focus is on outcomes rather than outputs.

The definition of these experienced service levels and their monitoring and enforcement framework should cascade into how the MaaS integrator and its service providers manage and operate their services. As a key example, providers should move away from managing incidents that impact individual transport modes but rather take a whole-of-ecosystem approach to ensure how end-to-end multimodal customer journey requirements can be met. This philosophy is often described as moving from "continuity of service" outcomes to supporting the "continuity of mobility".

d) Engage the market to design a procurement model to pilot an accessibility-based multimodal service contract in a defined geographic area

Procuring a total mobility provider based on delivered levels of accessibility constitutes a unique world-first and transposes a concept that has existed (in its entirety) only in theory into practice. Key questions need to be addressed around the number of MaaS integrators within metropolitan Melbourne, the exclusivity of these mode-agnostic mobility contracts, how MaaS integrators interact with existing transport service providers, the definition of contract boundaries (and how boundary issues can be resolved), as well as how train and tram operators who already serve a large population base via linear corridors are treated. Extensive engagement with the market is required to work through these issues.

A more prudent approach may be to pilot mode-agnostic mobility contracts in a defined precinct environment. Trialling a MaaS solution based on a full market resolution in a greenfield growth estate on the metropolitan fringe may be most palpable, allowing close integration with the precinct's development as well reducing the risks and impacts of any unintended consequences or lapse in-service performance.

e) Evaluate service performance and value-for-money on a total mobility (mode shift) basis

Service performance measures for a total mobility contract must move away from intermediate objectives such as service kilometres or on-time running to ultimate objectives like mode shift, carbon emissions reductions, shifts in automobile ownership, and social inclusion measures like accessibility. Methods to capture pain points in travel, such as the need and ease of transfer (given this project's interest in the first/last mile), are also warranted.

To fully study the success of a total mobility approach to procuring transportation, value-for-money and scalability objectives need to be considered. Market failures such as unintended competition or fragmentation with existing mode-specific providers need to be examined, as well as the likely cost of enforcement for compliance-related requirements and upstream regulatory/governance changes and associated disruptions. The results of a full impact analysis on all stakeholders as compared with the status quo (or counterfactual) can help inform to what extent mode-agnostic mobility contracts might be able to be scaled more widely.

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Appendix

A1. Recent evidence for the impact of TNC-enabled modes on public transport patronage

Mode	Publication	Locality (Study period)	Public transport impact (by mode where available)
Ridehailing	Graehler Jr. et al. (2019)	22 US cities (2002-18)	Rail and bus decrease
	Boisjoly et al. (2018)	25 North American cities (2002-15)	Not statistically significant
	Schaller (2018)	New York City (2016-17)	Public transport decrease
	Clewlow and Mishra (2017)	7 US cities (2015-16)	Bus and light/heavy rail decrease
	Hall et al. (2017)	US cities (2004-15)	Public transport increase
	Mucci (2017)	San Francisco (2016)	Bus decrease, but not rail
	Sadowsky and Nelson (2017)	28 US cities (assorted)	First entry increase, second entry decrease
	Rayle et al. (2016)	San Francisco (2014)	Public transport both increase and decrease
Carsharing	Martin and Shaheen (2011)	18 North American cities (2008)	Mixed but generally public transport increase
	Lane (2005)	Philadelphia (2003)	Public transport increase
Bikesharing	Graehler Jr. et al. (2019)	22 US cities (2002-18)	Light/heavy rail increase, bus decrease
	Campbell and Brakewood (2017)	New York City (2013-14)	Bus decrease
	Ma et al. (2015)	Washington, D.C. (2013)	Rail increase
	Shaheen et al. (2013)	4 North American cities (2011-12)	Bus both increase and decrease

A2. Project plan

Sprint 1: Case study identification	• Develop composite accessibility measure (PTAL) • Analyse public transport availability/propensity • Overlay with population (density) and mode share	• Identify public transport deserts • Select 6-8 case studies • Finalise 4-6 given political imperative
Sprint 2: Ground-truthing	• Develop end user survey questions • Pilot test survey and engage market research firm • Administer survey instrument	• Identify barriers and facilitators to public transport use • Ascertain extent of first/last mile as constraint
Sprint 3: In-depth diagnosis	• Deep dive on accessiblity/connectivity challenges • Consider package of improvement opportunities	• Demonstrate theoretical benefits of multimodal integration
Sprint 4: Stakeholder liaison	• Key informant interviews with operators, etc. • Ascertain interest and key barriers to collaboration	• Develop policy and institutional reform priorities • Clarity on MaaS vision from stakeholders
Sprint 5: MaaS options generation	• Develop MaaS operational parameters • Investigate technical requirements (e.g., data, app)	• Develop MaaS alternatives bespoke to local context • Formulate plan to bring to fruition
Sprint 6: Innovations development	• Ideate and co-create innovations • Report writing and branding input	• Deliver final outcomes report to internal project stakeholders

A3. MaaS bundle examples from ODIN PASS

UQ Student pricing

Lite Concession	Plus Concession	Premium Concession
~~$59~~ $29	~~$89~~ $44	Coming Soon
✔ Special introductory offer: 50%+ discount	✔ Special introductory offer: 50%+ discount	✔ Special introductory offer
✔ Equates to only $7.25 per week or less than $1.00 per day	✔ Equates to only $11.00 per week or less than $1.50 per day	✔ Competitive equivalent weekly and/or daily cost
✔ 30-days access	✔ 30-days access	✔ 30-days access
✔ Unlimited public transport trips in South East Queensland (excl. AirTrain)	✔ Unlimited public transport trips in South East Queensland (excl. AirTrain)	✔ Unlimited public transport trips in South East Queensland (excl. AirTrain)
● Pay per trip on Neuron e-scooters & e-bikes	✔ Unlimited Neuron e-scooter & e-bike trips up to 90 minutes per day	✔ Unlimited Neuron e-scooter & e-bike trips up to 90 minutes per day
● Pay per trip on taxis, ride-sharing & car-sharing	● Pay per trip on taxis, ride-sharing & car-sharing	✔ 5 to 10% discount on taxis, ride-sharing & car-sharing

UQ staff pricing

Lite	Plus	Premium
~~$89~~ $44	~~$119~~ $59	Coming Soon
✔ Special introductory offer: 50%+ discount	✔ Special introductory offer: 50%+ discount	✔ Special introductory offer
✔ Equates to less than $1.50 per day	✔ Equates to less than $2.00 per day	✔ Competitive equivalent daily cost
✔ 30-days access	✔ 30-days access	✔ 30-days access
✔ Unlimited public transport trips in South East Queensland (excl. AirTrain between Eagle Junction and Airport)	✔ Unlimited public transport trips in South East Queensland (excl. AirTrain between Eagle Junction and Airport)	✔ Unlimited public transport trips in South East Queensland (excl. AirTrain between Eagle Junction and Airport)
● Pay per trip on Neuron e-scooter & e-bikes	✔ Unlimited Neuron e-scooter & e-bike trips up to 90 minutes per day	✔ Unlimited Neuron e-scooter & e-bike trips up to 90 minutes per day
● Pay per trip on taxis, ride-sharing & car-sharing	● Pay per trip on taxis, ride-sharing & car-sharing	✔ 5 to 10% discount on taxis, ride-sharing & car-sharing

For more information, visit: https://odinpass.com.au

A4. Transport Integration Act

Vision

"The Parliament recognises the aspirations of Victorian for an integrated and sustainable transport system that contributes to an inclusive, prosperous and environmentally responsible State"

Transport system objectives

- Social and economic inclusion
- Economic prosperity
- Environmental sustainability
- Integration of transport and land use
- Efficiency, coordination and reliability
- Safety and health and wellbeing

Decision making principles

- Principle of integrated decision making
- Principle of triple bottom line assessment
- Principle of equity
- Principle of the transport system user perspective
- Precautionary principle
- Principle of stakeholder engagement and community participation
- Principle of transparency

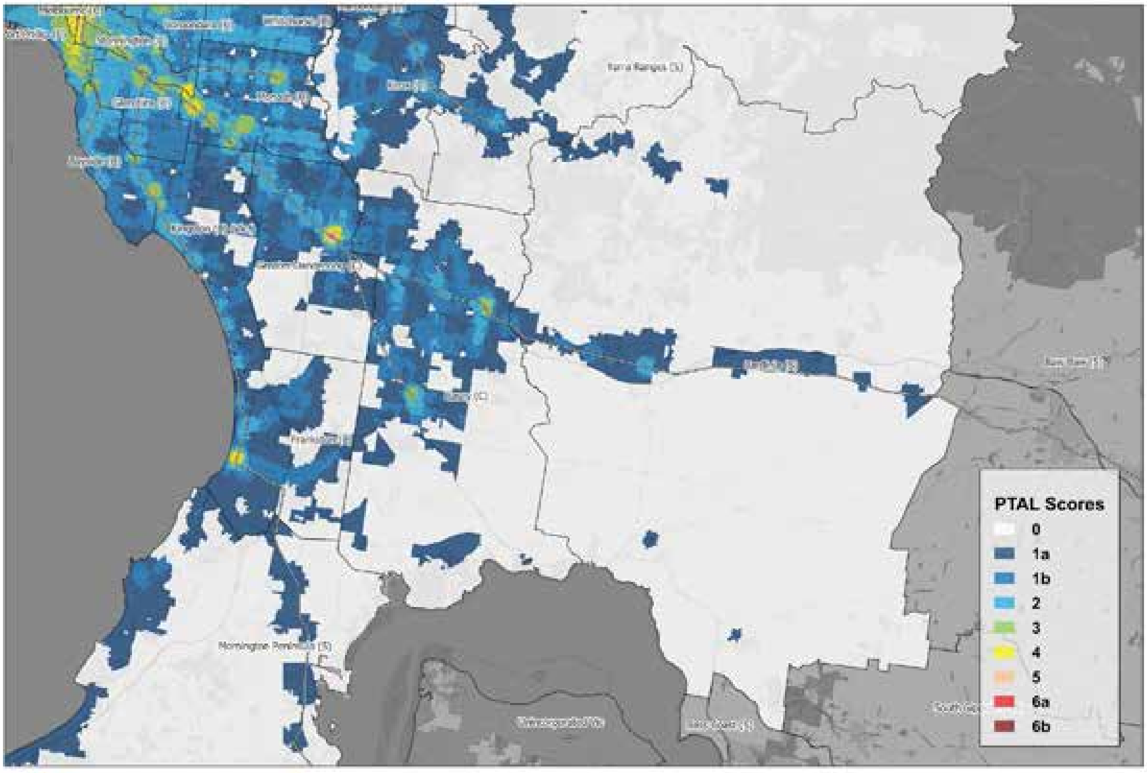
A5. Public transport accessibility level (PTAL) methodology

Step	Key facts
Calculate walk times to service access points (SAPs)	• There are about 13,000 SAPs in Greater London. Not every bus stop is a separate SAP. If several stops are very close to each other then they are coded as a group • A walking speed of 4.8 kph is assumed in the calculation • The walk network is created from the Integrated Transport Network (ITN) published by Ordnance Survey, which includes all of London's roads. Motorways and major trunk roads have been removed as they are not suitable for walking. Rail bridges, footpaths and local short cuts have been added • The calculation assumes that people will walk up to 640 metres (approximately eight minutes) to a bus service and up to 960 metres (12 minutes) to a rail or Tube service. Services available at a longer distance do not affect the PTAL of a selected location. The walk access distance is measured using software such as RouteFinder, an application of the MapInfo package • Information on bus stops and routes is taken from TfL's BusNet data • Rail, Tube and tram station locations and frequencies are derived from our strategic public transport model, Railplan. A separate publication on our website describes the Railplan tool
Calculate scheduled waiting time (SWT) for each route at each SAP	• The standard PTAL calculation is based on service frequencies in the period between 08:15 and 09:15 on a weekday • Passengers are assumed to arrive at the station point at random, without adjusting their arrival to the bus timescale, as is common with frequent urban services • The SWT (in minutes) is estimated as half the time interval between arrivals of the service at the SAP, i.e. SWT = 0.5 * (60/frequency) • For example, a bus service with a frequency of six buses per hour will have an interval of 10 minutes and a SWT of five minutes, which is the average amount of time a passenger who arrives randomly will have to wait • If a single route has several stops in the area we look at, only the nearest is considered • PTAL considers directions in a simplified way. If a service runs in both directions, the most frequent direction is used in the calculation • For rail services, only those with at least two stops within London are considered. So the PTAL near major stations does not consider services that do not stop elsewhere in London
Calculate average waiting times (AWT) for each route at each SAP	• The AWT (in minutes) equals the SWT plus a reliability factor. The reliability factor varies by mode of transport. It reflects the fact that actual wait times can be longer because services do not arrive in an entirely regular manner • A reliability factor of two minutes is used for buses and a factor of 0.75 minutes is used for rail, Tube or tram services

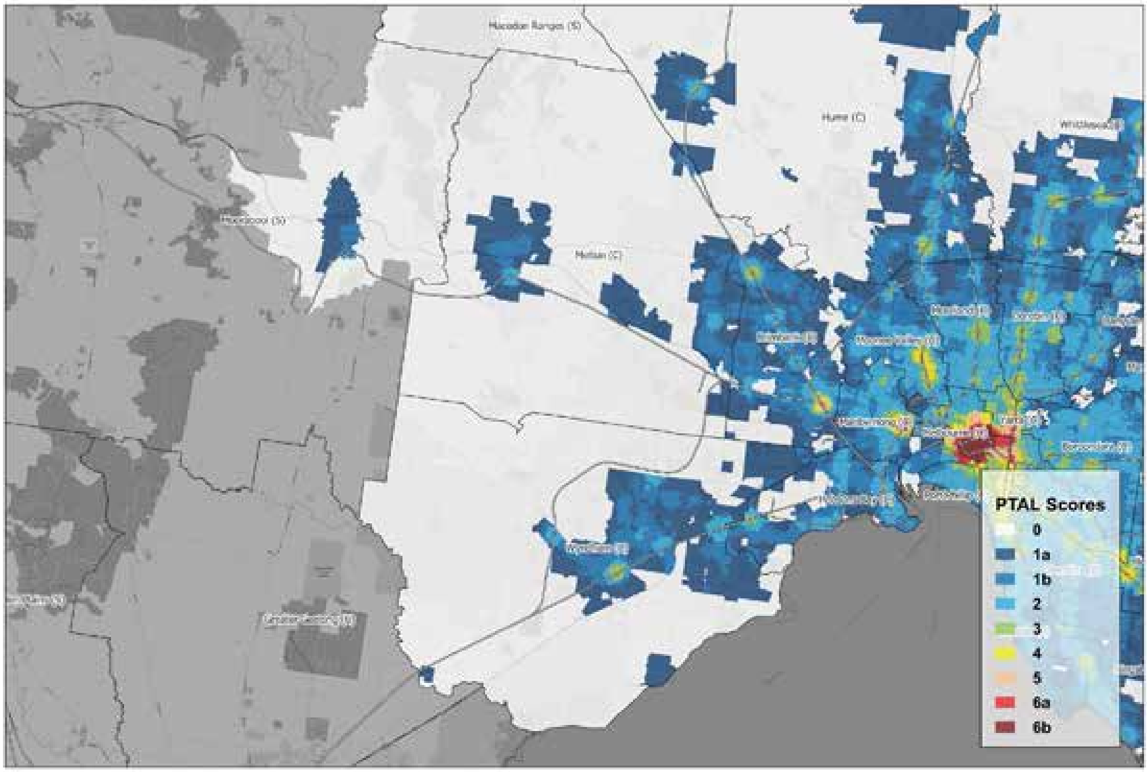
Step	Key facts
Calculate total access time (TAT) for each route at each SAP	• The TAT (in minutes) combines the walk time to the SAP with the AWT at the SAP, i.e. TAT = walk time + AWT
Calculate equivalent doorstep frequency (EDF) for each route at each SAP	• The EDF (in minutes) converts the TAT back into units of frequency, i.e. EDF = 0.5 * (60 / TAT). It is a measure of what the service frequency would be like if the service was available without any walk time
Calculate Access Index (AI)	• It is common that for each mode of transport available for a certain journey, a specific route from a specific nearby stop or station is the most suitable. The PTAL method simplifies this by giving a higher weight to the single service with the highest EDF for each mode, and a lower weight to other services within the same mode • The AI is therefore based on summarising the EDFs of all routes at all SAPs (within the acceptable walking distance), but giving a weigh of one to the highest EDF per mode and a weight of 0.5 to all other EDFs. The calculation of the AI for each specific mode is AI = Largest EDF + 0.5 * Σ(all other EDFs) • A separate AI is initially calculated this way for buses, rail, Tube (including Docklands Light Railway) and tram • A total AI is then calculated for the selected location, as the sum of the AIs across all modes, i.e. $AI_{total} = \Sigma(AI_{bus} + AI_{rail} + AI_{Tube} + AI_{tram})$
Convert to PTAL	• The AI is converted to PTAL using the bands specified in table 2.2

A6. Public transport accessibility level (PTAL) sub-region outputs for Melbourne

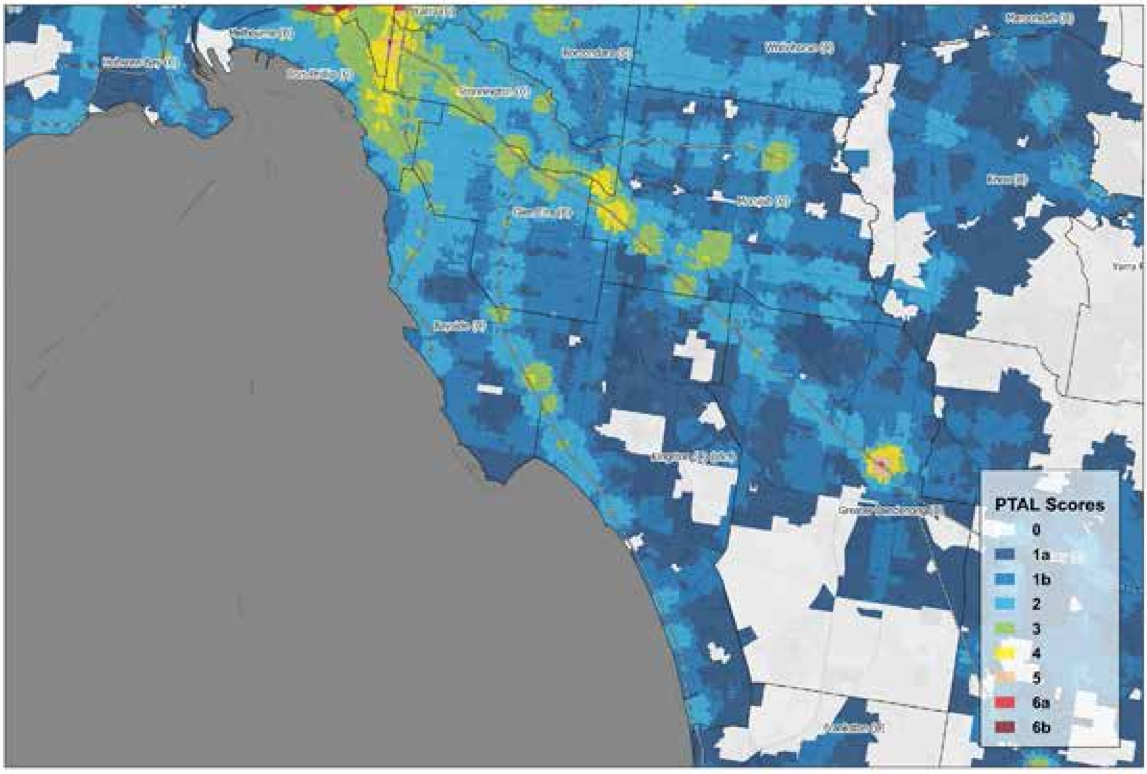
PTAL Scores - Melbourne - South East



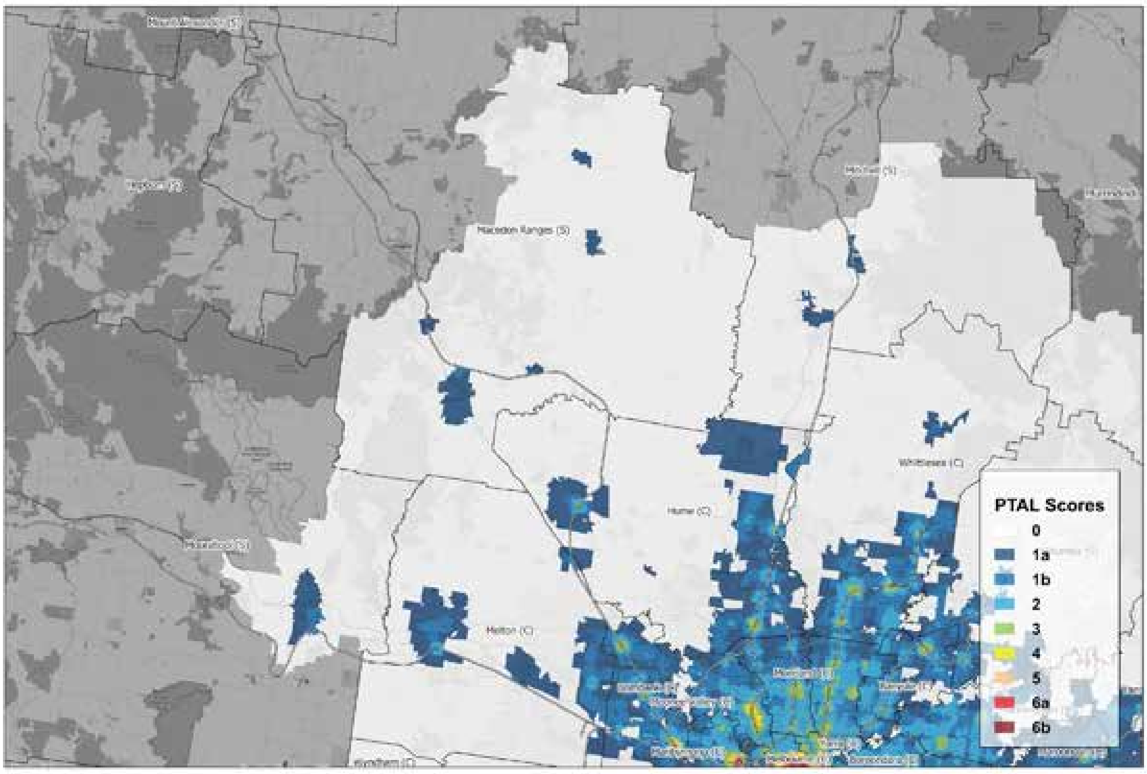
PTAL Scores - Melbourne - West



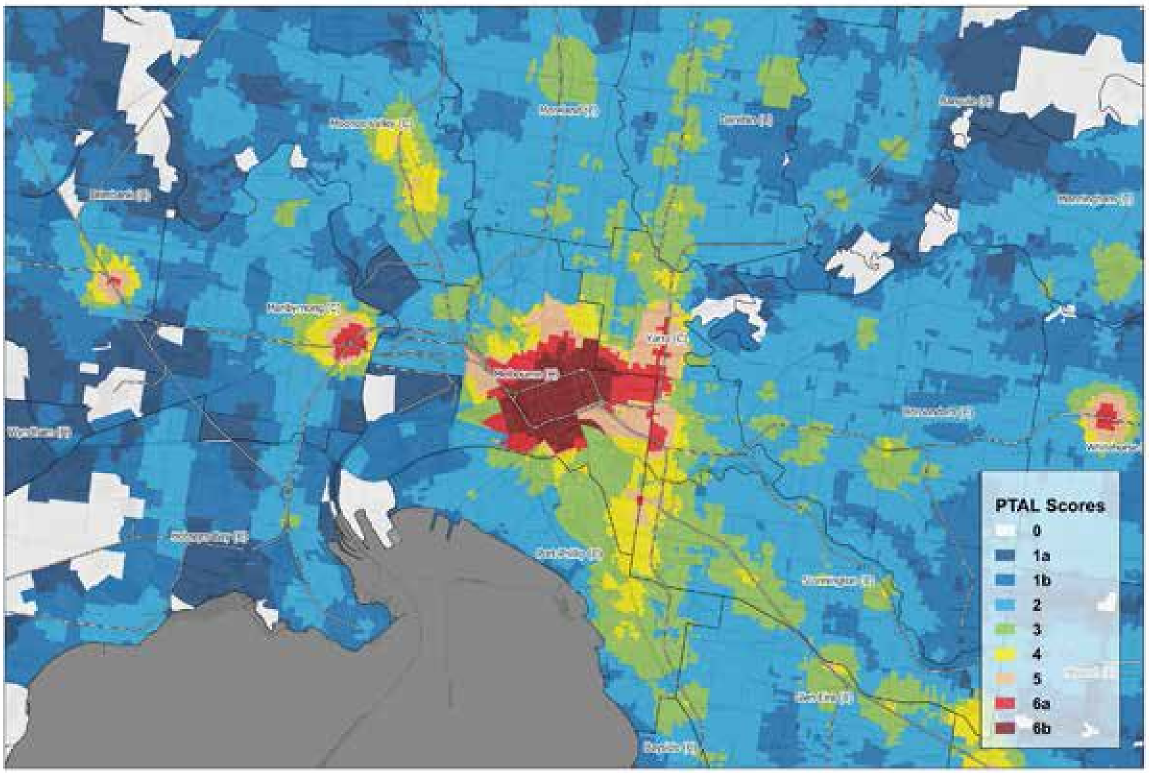
PTAL Scores - Melbourne - Inner South



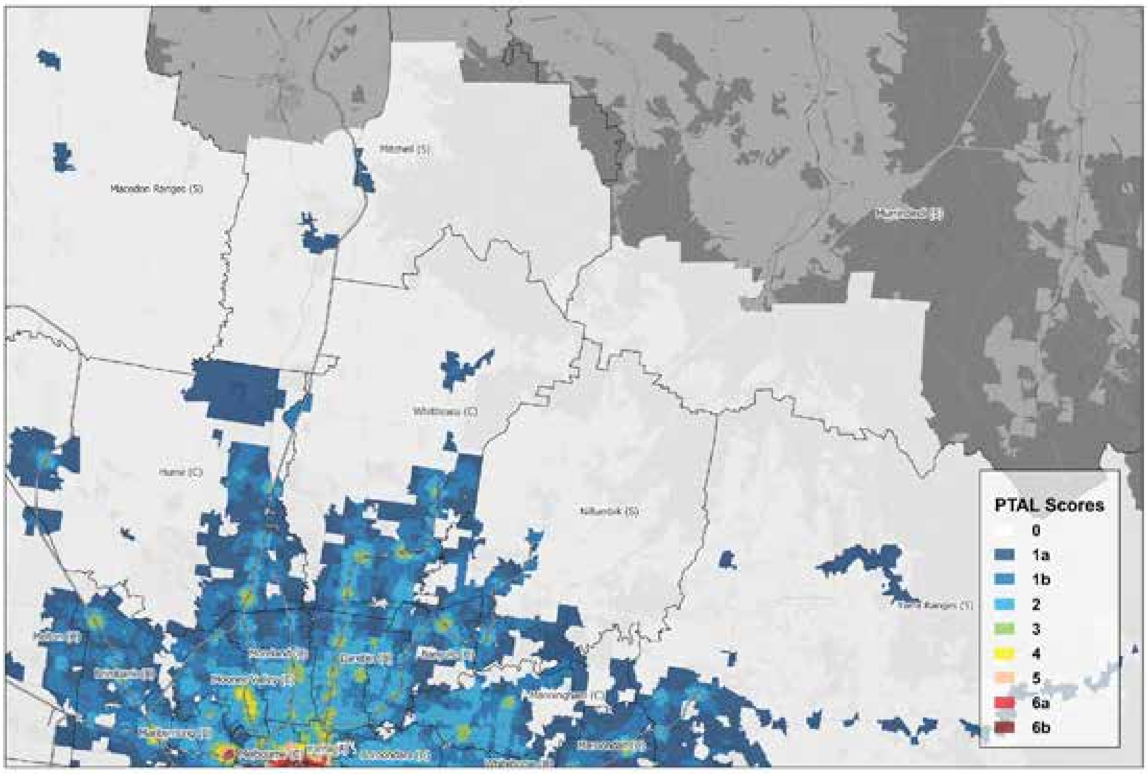
PTAL Scores - Melbourne - North West



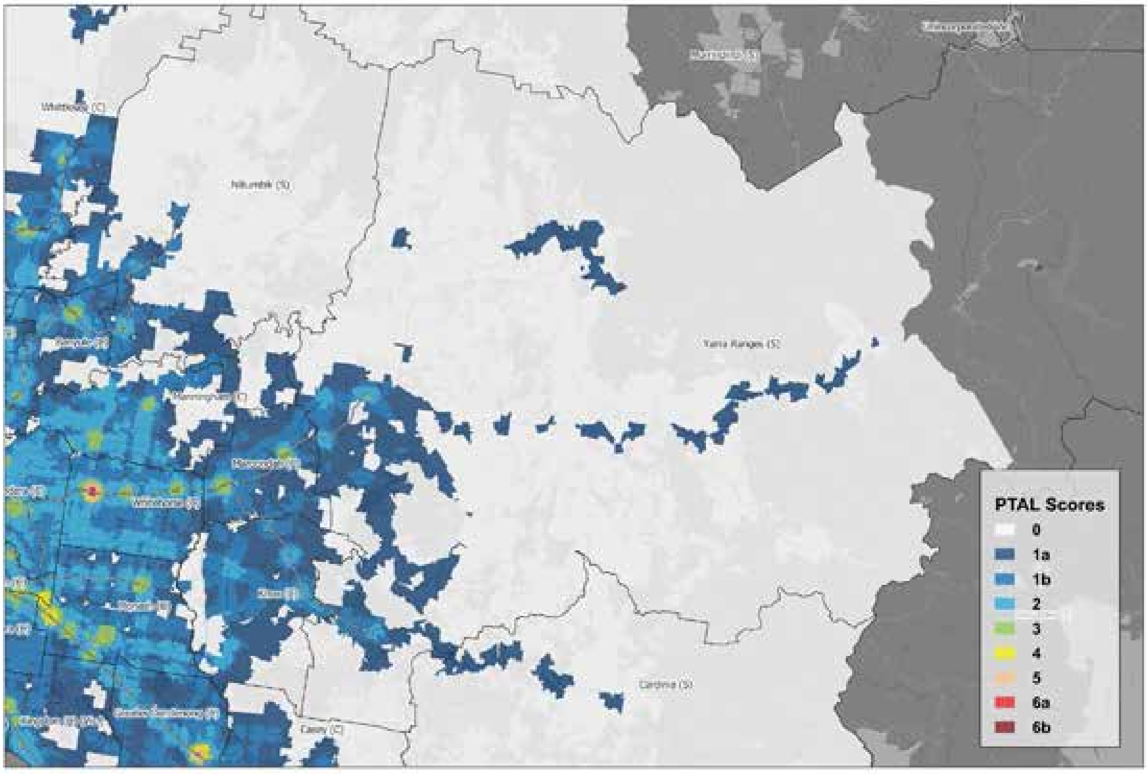
PTAL Scores - Melbourne - Inner



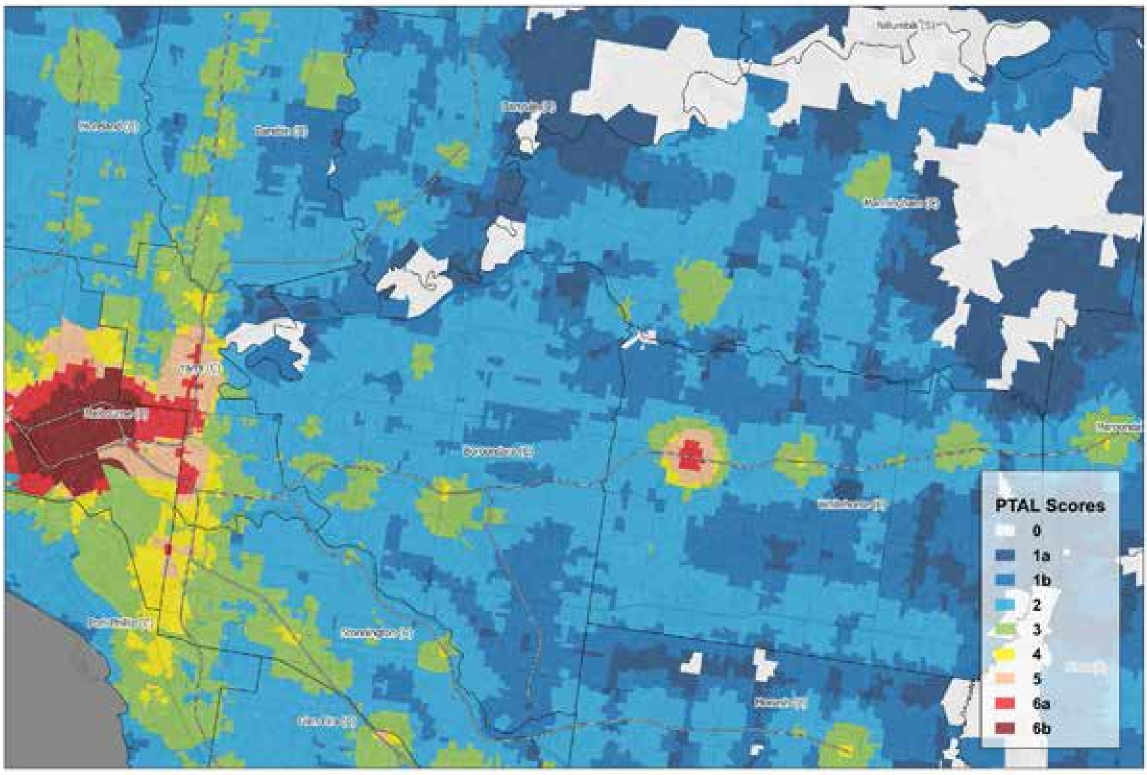
PTAL Scores - Melbourne - North East

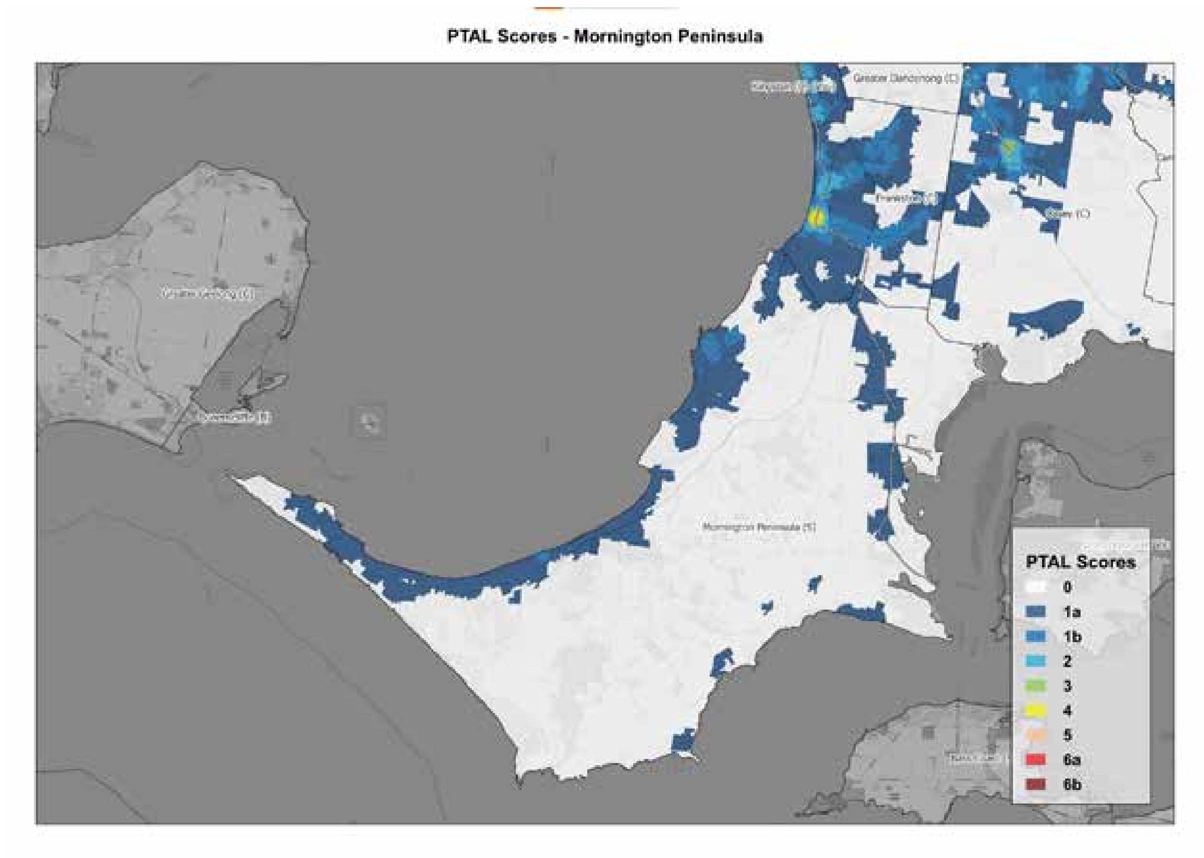


PTAL Scores - Melbourne - Outer East



PTAL Scores - Melbourne - Inner East




PTAL Scores - Mornington Peninsula
Greater Dandenong (C)
Mornington Peninsula (S)
PTAL Scores
0
1a
1b
2
3
4
5
6a
6b

A7. Station intercept survey questionnaire

Part 1: Travel mode choice

Station intercept survey

Safety first. Please walk respondents through the survey. All responses are to be inputted by the survey crew.

Please introduce the survey with:
"Hi, I'm XXX from PBA Transit Planning. We are running a survey to understand how people travel to the train station. Would you be interested in participating in a quick 3 min survey to help improve transport in the local area?

Note: Do not approach school students. Use your judgement and stand at an appropriate location outside the station paid area.

This survey is designed for both access and egress trips. Parentheses provide appropriate wording in the case of egress trips.

* Required

1. Travel mode choice

1. How did (will) you travel to (from) the station? Answer by observation where appropriate. *

- Car as driver
- Car as passenger (walked from parked car)
- Car as passenger (dropped off)
- Motorbike
- Bus
- Bicycle (or PMD)
- Walk
- Taxi
- Uber (etc.)

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Part 2 Stream A: Driver-specific

Station intercept survey

2a. Driver-specific

2. How long were you (will you be) in the car/motorcycle?

- ◯ <5 min
- ◯ 6-10 min
- ◯ 11-15 min
- ◯ 16-20 min
- ◯ 21+ min
- ◯ Other

3. Did you (Will you) undertake another activity as part of this trip?

- ◯ No
- ◯ Yes—school run
- ◯ Yes—shopping
- ◯ Yes—appointment
- ◯ Other

4. How long did (will) you walk from your parked car to the station (the station to your parked car)?

- ◯ <5 min
- ◯ 6-10 min
- ◯ 11-15 min
- ◯ 16-20 min
- ◯ 21+ min

5. Have you considered using the bus?

- ☐ No
- ☐ Yes, but bus stop is too far from home
- ☐ Yes, but wait times are too long/unreliable
- ☐ Yes, but inconvenient times/schedules
- ☐ Yes, but no service available on the return leg
- ☐ Yes, but have to trip chain
- ☐ Other

6. How would you travel to (from) the station if your car was not available?

- ◯ Would not travel to station
- ◯ Get a lift
- ◯ Taxi/Uber
- ◯ Bus
- ◯ Walk
- ◯ Bicycle
- ◯ Would not travel at all

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Part 2 Stream B: Passenger-specific

Station intercept survey ...

2b. Passenger-specific

2. How long were you (will you be) in the car?

- ○ <5 min
- ○ 6-10 min
- ○ 11-15 min
- ○ 16-20 min
- ○ 21+ min

3. Who was (will be) the driver of your vehicle?

- ○ [BY INSPECTION] Professional driver
- ○ Spouse
- ○ Parent
- ○ Children
- ○ Sibling
- ○ Housemate
- ○ Neighbour
- ○ Other

4. Have you considered using the bus?

- ☐ No
- ☐ Yes, but bus stop is too far from home
- ☐ Yes, but wait times are too long/unreliable
- ☐ Yes, but inconvenient times/schedules
- ☐ Yes, but no service available on the return leg
- ☐ Yes, but have to trip chain
- ☐ Other

5. How would you travel to/from the station if your ride wasn't available?

- ○ Would not travel to station
- ○ Drive own car
- ○ Get a lift
- ○ Taxi/Uber
- ○ Bus
- ○ Walk
- ○ Bicycle
- ○ Would not travel at all

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Part 2 Stream C: Bus-specific

Station intercept survey ...

2c. Bus-specific

2. How long does it take to walk from your home to the local bus stop (from the local bus stop to your home)?

- ◯ <5 min
- ◯ 6-10 min
- ◯ 11-15 min
- ◯ 16-20 min
- ◯ 21+ min

3. How long did you (will you) wait for the bus?

- ◯ <5 min
- ◯ 6-10 min
- ◯ 11-15 min
- ◯ 16-20 min
- ◯ 21+ min

4. How long were you (will you be) on the bus?

- ◯ <5 min
- ◯ 6-10 min
- ◯ 11-15 min
- ◯ 16-20 min
- ◯ 21+ min

5. Why do you choose to travel by bus? Please select all that is applicable.

- ☐ Cost saving
- ☐ No access to car
- ☐ No need to find parking
- ☐ Environmental benefits
- ☐ Ability to do work onboard
- ☐ Ability to socialise
- ☐ Other

6. What is your bus route number? Answer by observation where appropriate.

Enter your answer

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Part 2 Stream D: Active-specific

Station intercept survey ...

2d. Active-specific

2. How long does it (will it) take to walk/ride from your home to the station (from the station to your home)?

- ○ <5 min
- ○ 6-10 min
- ○ 11-15 min
- ○ 16-20 min
- ○ 21+ min

3. Why do you choose to walk/ride? Please select all that is applicable.

- ☐ Too close to drive/bus (self-evident)
- ☐ Cost saving
- ☐ No access to car
- ☐ No need to find parking
- ☐ Opportunity to exercise
- ☐ Opportunity to trip chain
- ☐ Other

4. How can we improve your walk/ride quality? Please select all that is applicable.

- ☐ Wider paths and less obstacles
- ☐ Better pavement quality
- ☐ Better accessibility (e.g. ramps)
- ☐ Better lighting
- ☐ More direct/extensive network (including missing links)
- ☐ More pleasant environment (beautification)
- ☐ Signalising intersections
- ☐ Better separation from traffic
- ☐ Other

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Part 3: About your travel

Station intercept survey ...

3. About your travel

7. How long will you be (were you) on the train today?

- ◯ <10 min
- ◯ 11-20 min
- ◯ 21-30 min
- ◯ 31-40 min
- ◯ 41-50 min
- ◯ 51-60 min
- ◯ 61+ min

8. What is the purpose of your trip? Choose a main trip purpose.

- ◯ Full-time work
- ◯ Part-time work
- ◯ University/TAFE
- ◯ School
- ◯ Shopping
- ◯ Recreation
- ◯ Healthcare
- ◯ Other

9. How many days will you make your trip this week?

- ◯ 6-7 days
- ◯ 4-5 days
- ◯ 2-3 days
- ◯ 1 day

10. Where are you travelling from (to)? Please provide a street name and (if you desire) a suburb or cross-street.

Enter your answer

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Part 4: About the respondent

Station intercept survey

* Required

4. About the respondent

Please complete this section by observation only.

10. [INTERNAL] Surveyor name. This will help pinpoint the survey session. *

- ○ Testing (Please select if the data should not be captured)
- ○ Balwant
- ○ Boris
- ○ Domingo
- ○ Jennifer
- ○ Leigh
- ○ Mei
- ○ Mustafizur
- ○ Song
- ○ Nick
- ○ Callan

11. [BY INSPECTION] Travel direction *

- ○ Access
- ○ Egress

12. [BY INSPECTION] What is the respondent's gender? *

- ○ Male
- ○ Female

13. [BY INSPECTION] What is the respondent's age bracket? *

- ○ School (<18)
- ○ Younger (19-35)
- ○ Middle (36-55)
- ○ Older (56-75)
- ○ Senior (>76)

14. [BY INSPECTION] What is the ethnicity of the respondent? *

- ○ Caucasian
- ○ East Asian
- ○ South Asian
- ○ Middle-Eastern
- ○ Hispanic/Latino
- ○ African
- ○ Indigenous Australian
- ○ Other

15. [BY INSPECTION] Does the respondent have any specific mobility requirement? Choose a main requirement. *

- ○ None
- ○ Pram
- ○ Children
- ○ Bicycle
- ○ Wheelchair
- ○ Luggage
- ○ Mobility device (including canes)

16. Any other information shared by the respondent?

Enter your answer

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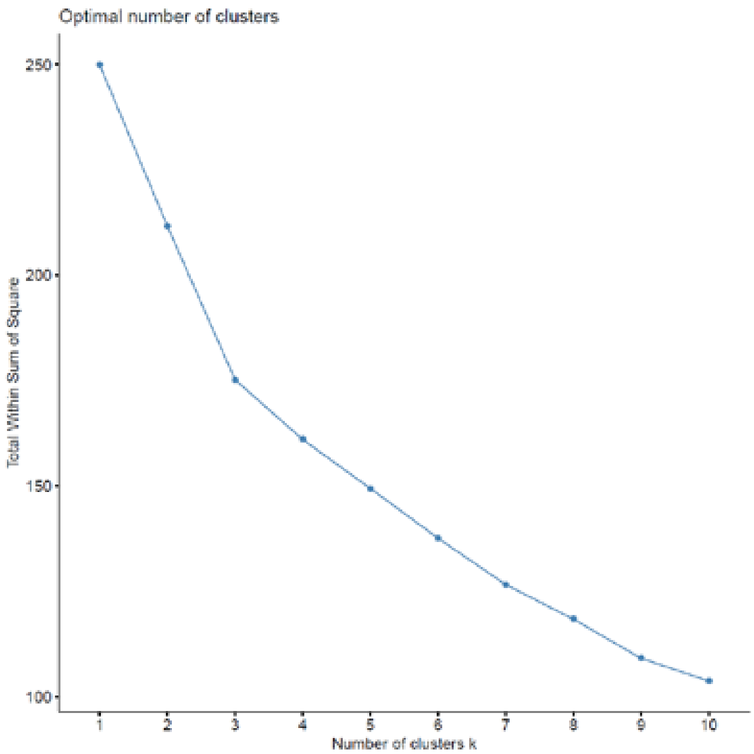
A8. Survey sample descriptive statistics

	Cranbourne	**Williams Landing**	**Grand Total***
Travel Direction			
Access	69	11	80
Egress	22	30	52
Gender			
Female	45	22	67
Male	46	19	65
Age			
School (<18)	2		2
Younger (19-35)	49	22	71
Middle (36-55)	30	17	47
Older (56-75)	10		10
Senior (>76)		2	2
Ethnicity			
African	5	1	6
Caucasian	42	15	57
East Asian	15	5	20
European	1		1
Hindu		1	1
Hispanic/Latino	2	1	3
Indian		4	4
Middle-Eastern	10		10
New Zealander		2	2
South Asian	16	12	28

*n=132 (sum of responses within each attribute category is 132)

A9. K-means clustering

The below figure shows how k=6 clusters are obtained based on similarities. This is based on the statistical criteria of maximising between groups difference while minimising within groups difference.



A10. Case study network structure characteristics

Point Cook

Route	**495**	**494**	**497**	**498***
Description	Williams Landing Station - Point Cook South via Boardwalk Bvd	Williams Landing Station - Point Cook South via Alamanda Bvd	Williams Landing Station - Saltwater Coast Estate via Sanctuary Lakes SC	Laverton Station - Hoppers Crossing Station via Dunnings Rd
Function	Feeder	Feeder	Feeder	Local
Weekday Span	06:00-21:30 (00:30)	06:00-21:30 (00:30)	06:00-21:30	06:00-21:30
AM Peak	4	3	3	3
Inter-peak	1.5	1.5	1.5	1.5
PM peak	6	3	3	3
Saturday	1.5	1.5	1.5	1
Sunday	1.5	1.5	1.5	1
Notes	Friday/Saturday evening extended hours	Friday/Saturday evening extended hours		Peak short work Point Cook-Hoppers Crossing

Cranbourne East

Route	**798**	**898**	**897**	**796***	**888****
Description	Cranbourne Park SC - Selandra Rise	Cranbourne East - Cranbourne Station via Cranbourne Park SC	Clyde - Lynbrook Station	Cranbourne Station - Clyde	Clyde - Berwick Station
Function	Feeder	Feeder	Local	Feeder	Feeder
Weekday Span	06:00-22:00	06:00-21:30	06:00-21:30	06:30-21:00	06:30-21:30
AM Peak	4	3	3	0.67	1
Inter-peak	3	3	3	0.5	1
PM peak	4	3	3	0.5	1
Saturday	3	1.5	3	0.5	1
Sunday	3	1	3	0.5	1
Notes	40 min gap in AM peak				

Doreen

Route	**381**	**388**	**389**
Description	Mernda Station to Diamond Creek Station	Mernda Station - Doreen - Mernda Station (Anti-clockwise)	Mernda Station - Doreen - Mernda Station (Clockwise)
Function	Regional	Feeder	Feeder
Weekday Span	06:00-21:30	06:00-22:00	06:00-21:30
AM Peak	3	3	4
Inter-peak	1.5	1.5	1.5
PM peak	3	3	4
Saturday	1.5	1.5	0
Sunday	1.5	1.5	0
Notes	Peak short work Mernda-Doreen		

Rowville

Route	**681**	**682**	**691**	**FlexiRide**
Description	Lysterfield - Knox City via Wantirna & Scoresby & Rowville (clockwise)	Lysterfield - Knox City via Wantirna & Scoresby & Rowville (anti-clockwise)	Boronia - Waverley Gardens via Ferntree Gully & Stud Park	Anywhere to Stud Park SC or Ferntree Gully station
Function	Feeder/Local	Feeder/Local	Regional	Feeder
Weekday Span	06:30-18:30	06:30-18:30 (21:30)	06:00-21:30	06:00-20:00
AM Peak	3	2	3	On demand
Inter-peak	0.5	0.5	2	On demand
PM peak	0	1	3	On demand
Saturday	1	1 (0.5)	1.5	None
Sunday	1 (0.5)	1/0.5	1	None
Notes	AM peak only Lysterfield-Stud Park; Off-peak/PM peak/weekend extensions to Knox City	AM peak only Rowville-Stud Park; Off-peak/PM peak/weekend extensions to Knox City		Download application

Bentleigh East

Route	**630**	**703**	**824**	**626**	**627**	**822**	**701**	**767**
Description	Elwood - Monash University via Gardenvale & Ormond & Huntingdale	Middle Brighton - Blackburn via Bentleigh & Clayton & Monash University	Moorabbin - Keysborough via Clayton & Westall	Middle Brighton - Chadstone via McKinnon & Carnegie	Moorabbin Station - Chadstone SC via Bentleigh	Chadstone SC - Sandringham via Murrumbeena & Southland SC	Oakleigh - Bentleigh via Mackie Road & Brady Road	Southland - Box Hill via Chadstone & Jordanville & Deakin University
Function	Trunk	Trunk	Regional	Regional	Local	Regional	Local	Trunk
Weekday Span	06:00-22:00	06:00-20:00	06:30-21:30	07:00-21:00	06:00-21:00	06:00-22:30	06:30-21:30	06:00-21:00
AM Peak	6	4	3	2	2	2	2	3
Inter-peak	3	4	3	2	2	2	2	2
PM peak	6	4	3	2	2	2	2	3
Saturday	2	2	(3) 1	1	1.5 (2)	2	1	2
Sunday	1.5	2	1	1	1.5 (2)	1	1	1.5
Notes		35 min gap in AM peak	AM peak short work within 1 min of full route service; Sat AM extra short work		Saturday evening extra service; Sunday AM/PM peak extra service			

A11. MaaS readiness in Melbourne

Pillar	Indicator	Unit	Unit	Score	Melbourne
Market Potential	Number of modes that may be integrated under MaaS	Number	1	1	5
			2	2	
			3	3	
			4	4	
			>5	5	
	Percentage of public transport trips	Percentage	<10%	1	2
			10%-20%	2	
			20%-30%	3	
			30%-40%	4	
			>40%	5	
	Vehicle ownership rate	Private vehicles per person	<0.2	5	1
			0.2-0.5	3	
			>0.5	1	
Policy Readiness	Open data standard for transport services	Yes/No	Yes	5	3
			Partially	3	
			No	1	
	Data security and privacy regulation	Yes/No	Yes	5	3
			Partially	3	
			No	0	
	Third party ticket sales for transport services	Yes/No	Yes	5	1
			No	1	
	Strategic focus	Details	No strategic focus to support MaaS	1	2
			Planning to implement MaaS	2	
			Policy to specifically support MaaS	3	
			Have funding support for MaaS	4	
			Have funding and team for MaaS	5	

Pillar	Indicator	Unit	Unit	Score	Melbourne
Data Availability	Data collection	Details	Static data	1	3
			Real time traffic data	3	
			Real time passenger data	5	
	Data sharing	Details	Local authority has not opened data gathered from public transportation operation	1	4
			Local authority has opened data/standardized information gathered so that third parties can use it to create new apps and services	3	
			Third parties already use open data and provide mobile applications	4	
			Local authorities are promoting and facilitating a cooperation between different providers	5	
System Integration	ICT infrastructure	Internet connectivity	2G/3G connectivity	1	3
			Highspeed 4G/5G connectivity	3	
			Citywide public Wi-Fi	5	
	Smartphone penetration	Percentage of population with a smartphone	< 50%	1	5
			50%-70%	3	
			>70%	5	
	Smart ticketing infrastructure	Yes/No	No	1	3
			Limited to certain modes	3	
			Available for all mode with a single smart card	5	
	Contactless debit/credit card penetration	Yes/No	Yes	5	5
			Limited to certain users	3	
			No	1	
	Application programming interface (API)	Details	Private API availability	1	3
			Open API availability	3	
			Real time data via API	5	

Pillar	Indicator	Unit	Unit	Score	Melbourne
Travel Behaviour	Popularity of public transport	Historic trend on public transport patronage	Increasing	5	3
			Consistent	3	
			Reducing	1	
	Multimodal trips	Number of trips using more than one mode	More than 50% of trips use more than one mode	5	5
			Less than 50% of trips use more than one mode	3	
	Sensitivity to sustainable transport	Enabling environment	Pollution is a major concern and community is willing to adopt sustainable transport options	5	3
			Very challenging to move away from private transport culture	3	

A12. Safety-based e-scooter trial regulatory parameters proposed for Victoria

1. E-scooters will be limited to using low-speed roads (up to and including 50 kilometres per hour), bicycle lanes, bicycle paths, separated and shared paths (on the bicycle side, if specified) (3 penalty units).
    a. Note the 50km/h road limit always applies – i.e. you can ride an e-scooter in a bicycle lane provided that the lane is on a road with a speed limit of 50km/h or less.
2. E-scooters will not be permitted on footpaths (but are allowed on separated and shared paths) and high-speed roads (i.e. where the specified speed limit is above 50 kilometres per hour) (3 penalty units).
3. E-scooters must have a maximum speed of and not travel in excess of 20 kilometres per hour (3 penalty units).
4. E-scooter riders will be subject to blood alcohol content (BAC) and drug use restrictions applying to other motorists under the *Road Safety Act 1986* (penalties as per *Road Safety Act 1986*).
    a. While a driver licence is not required to operate an e-scooter, the penalties that apply under the RSA for breaching BAC/drug use restrictions will apply to the e-scooter rider's licence, should they have one.
5. A person must not consume alcoholic beverages while travelling on an e-scooter (5 penalty units).
6. Users must wear a helmet when operating an e-scooter (5 penalty units).
7. E-scooter riders must be at least 18 years of age (3 penalty units).
8. E-scooter use should be restricted to specific local government areas (LGAs) (3 penalty units).
9. Only e-scooters operated by share scheme commercial operators within participating LGAs can be used (no private e-scooters) (3 penalty units).
    a. *'Commercially operated share scheme'* is defined in the regulations as "a joint arrangement between a Council and a commercial operator to provide electric scooters for hire on a short-term basis to members of the public."
10. E-scooters must meet certain physical and hardware requirements (i.e. must have 2 wheels; built to transport one person while standing; is steered by means of a handlebar etc.). E-scooters are treated in the same way as bicycles in relation to brakes, warning device (bell), lights, reflectors, etc (2-5 penalty units).
11. E-scooter riders must adhere to certain behaviours, including that riders:
    a. have proper control at all times and ride with due care and reasonable consideration for road users and pedestrians (5 penalty units)
    b. use a warning (e.g. bell, horn or verbal) to avert danger
    c. not ride two abreast (3 penalty units)
    d. not carry passengers (3 penalty units)

e. give way to pedestrians (where appropriate, i.e. on a shared path; and keep left unless impractical) (3 penalty units)

f. not use a hand-held mobile phone whilst riding (10 penalty units)

g. not lead an animal, including by tethering the animal to the e-scooter (3 penalty units).

A13. MaaS data sharing protocols (ITS Australia, 2020)

Protocol	Gov.	Abst.	Mat.	Heritage	Ratifying authority	Description	Government benefits	Industry benefits	Consumer benefits
INSPIRE	10	1	3	EU	EU	The infrastructure for spatial information	Interoperability	Enabler	Enabler
GIP	9	2	3	EU	AITDI	Transport graph of public authorities	Interoperability	Enabler	Multi-modal journey planning
DATEX II	10	4	3	EU	CEN	Exchange of traffic information and traffic data	Interoperability	European journey planning	Traveller information
C2C/TMDD/ NTCIP	10	4	3	US	NEMA, AASHTO, ITE	Transportation centre to centre real-time exchange of information	Interoperability		
Transmodel	10	5	3	EU	CEN	Normative reference for higher level PT protocols	Enabler		
NeTEx	10	5	3	EU	CEN	Exchange of public transport Information	Interoperability	Interoperability	Journey planning
TransXChange	10	5	3	EU	UK DoT	Interchange of bus route and timetable information	Interoperability	Interoperability	Journey planning
SIRI	10	6	3	EU	CEN	Exchange real time information about public transport services and vehicles	Interoperability	Interoperability	Real time PT updates
OJP	10	8	3	EU	CEN	Long distance multi-modal journey planning	Interoperability		Enables long distance multi-modal journey planning
SUTI	9	9	3	EU	Sweden Ministry of Transport	Exchange of DRT information	Societal outcomes	Opens opportunities	Societal connections especially for the elderly and infirmed
OSM	5	3	3	EU	OpenStreetMap Foundation	A free editable map of the world	Access to free geospatial data	Access to free geospatial data	Enables routable journeys
APDS	5	5	2	EU	IPMI, BPA, EPA	Share parking data across platforms	Network efficiencies	Better use of resources	Informed parking choices
OTA	7	10	3	US	OTA	Exchange of traveller and supplier information in travel, tourism and hospitality		Enables supply chains	End to end travel experience
GBFS	4	2	3	US	NABA	Bike share findability	Network planning	Business efficiencies	Locate available bikes
TfNSW MaaS DS	3	4	2	AU	TfNSW	Reporting on MaaS operations	Evaluation efficacy of MaaS trial	Business intelligence	
MDS	4	4	3	US	OMF	Ingest, compare and analyse data from mobility service providers	Network monitoring and compliance	Compliance	Improved mode share outcomes
GTFS	4	5	3	US	Transit agencies and stakeholders	Public transportation schedules	Electronic distribution of PT information	Make PT more accessible	Informs journey planning
GTFS-RT	4	6	3	US	Transit agencies and stakeholders	Realtime public transportation updates	Electronic distribution of real time PT information	Make PT more accessible	Informs real time journey planning
HSL OpenMaaS API	3	8	3	EU	HSL	An open-for-all ticket sales interface for PT	Enables e-purchasing of PT	Enables a MaaS market	Seamless journey booking and payment.
GTFS-Flex	3	7	2	US	MobilityData	Models various demand-responsive transportation	Enables DRT	Lowers barrier to entry for DRT	Seamless DRT planning and booking experience
TDS for DRT	1	7	1	US	TRB	Proposal for a national DRT specification	Enables DRT	Lowers barrier to entry for DRT	Seamless DRT planning and booking experience
R5	2	8	2	US	N/A	Routing engine for multi-modal networks	Improve journey taker's experience	Improved journey planning	Journey planning that mirror human decision-making process
OTP	2	8	3	US	Transit agencies and stakeholders	Multi-modal trip planner	Lower barrier to entry	Provide third party journey planning apps	Increase journey planning app choice
MaaS TSP API	2	8	2	EU	Whim	Transport service provider API	Incorporate new TSPs into MaaS solution	Integrate into a MaaS solution	Improved mode options and seamless user interface
TSio Protocol	1	9	1	US	Travelspirit Foundation	Blockchain based multi-modal journey planning		Integrate into a distributed MaaS platform	Government free journey planning, booking and payment
ISO 24014-1	10	1	3	EU	ISO	PT – Interoperable fare management	Interoperability	Interoperability of systems	Seamless fare

A14. Ontario transit-supportive guidelines

Excerpt from the Ontario Ministry of Transportation (2012: 24)

Strategies Legend

Green Action

Applicable Community Scale

Small

Mid-size

Large

Big City

Planning Scale

(S) Site

(D) District

(M) Municipal

(R) Regional

Transit service type	Suggested minimum density
Basic Transit Service (One bus every 20-30 minutes)	22 units per ha / 50 residents & jobs combined
Frequent Transit Service (One Bus every 10-15 minutes)	37 units per ha / 80 residents & jobs combined
Very Frequent Bus Service (One bus every 5 minutes with potential for LRT or BRT)	45 units per ha / 100 residents & jobs combined
Dedicated Rapid Transit (LRT/BRT)	72 units per ha / 160 residents & jobs combined
Subway	90 units per ha / 200 residents & jobs combined

The table above illustrates suggested *minimum density thresholds* for areas within a 5-10 minute walk of transit capable of supporting different types and levels of transit service. The thresholds presented are a guide and not to be applied as standards. Other factors such as the design of streets and open spaces, building characteristics, levels of feeder service, travel time, range of densities across the network and mix of uses can also have a significant impact on transit ridership. *Mobility hubs* and major transit station areas may require higher minimum densities.

Last Mile Connectivity / MaaS Lite Feasibility Study

PBA Transit Planning for Bus Association Victoria

1 October 2021