Future Transport and Mobility Environment

(iMOVE 3-008)

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SUMMARY

Transport and mobility management involves a combination of people, processes, systems, and technology. With significant changes occurring in technology and mobility services, there is an opportunity and need to capture the current paradigm and plan for the emerging future transport and mobility environment (FTME). The current silos in land transport associated with private and commercial vehicles, and public transport (road and rail) are now beginning to change whereby service delivery is largely independent of the specific transport silo.

The project undertook an investigation to explore and challenge traditional approaches to transport operations and mobility in the face of new technologies and communications enabling greater integration of systems in the transport and mobility ecosystem.

Digitisation and advances in mobile communications have changed our lives significantly. There is a widespread sense that our world will be a much different place to live in, in the next 10-20 years. The unprecedented changes that are occurring to our everyday lives due to the global COVID-19 pandemic only serves to further bring forward the possibility of these changes. This assumption of continuity with the past is never guaranteed and today it is truer than ever. Almost all post-COVID scenarios will be predicated upon fundamental breaks with previous trends; this discontinuity is perhaps the only thing that can be reliably predicted.

The findings of this project can be summarised in the attached figure on the following page which shows, (i) the physical and digital infrastructure and (ii) the pantry of functional elements, in the lower half of the figure, and, (iii) the roles and responsibilities, in the top half of the figure.

The physical infrastructure of transport and mobility has been complemented by digital infrastructure and better connectivity between people, vehicles, infrastructure, and back offices. The Australian ‘pantry’ of core functional elements continues to expand and mature and these functional elements are utilised by the actors in the future transport and mobility environment in their roles, such as Service Providers, Transport Services, Transport Infrastructure Operators, Customers and Users as well as Governments as Regulators and System Managers.

While the roles and responsibilities today and in the future look similar, the increasingly integrated nature of transport and mobility calls for a fresh definition of roles and responsibilities of actors such as the System Manager and Regulator, which are currently the responsibility of several actors in road and rail networks, commercial and heavy vehicles, public transport and freight.

Further consideration and refinement of the FTME concept and roles among the stakeholders leading to a broad in-principle agreement would be helpful as it defines the forest from the trees and provides a sound context for alignment with other programs and projects.

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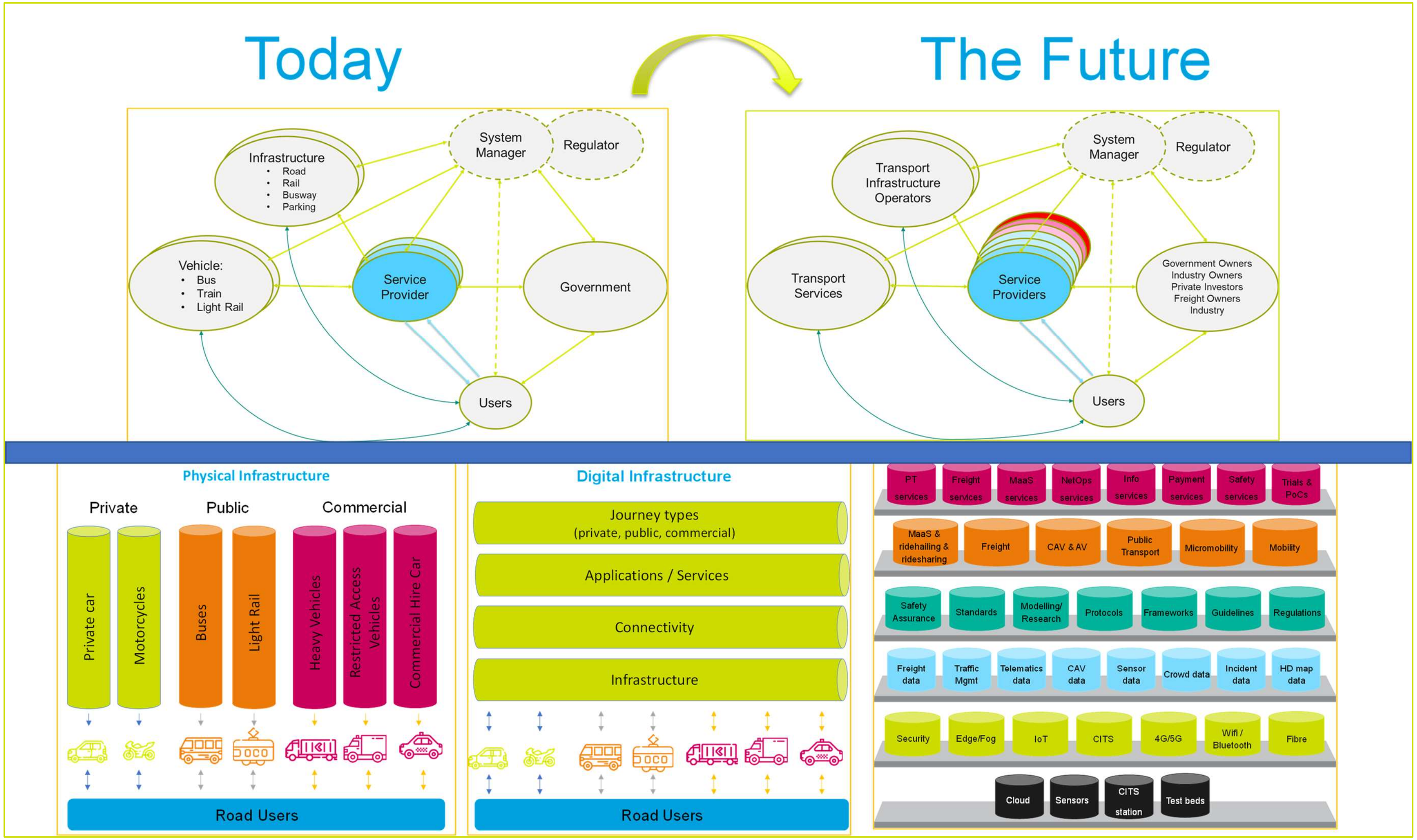

The development of a clear understanding around the conceptual and functional areas of a future transport and mobility ecosystem also provides the opportunity to disseminate this knowledge to other areas outside of transport, for example, to areas such as aviation, defence, freight, Big Data, safety, research and standards development.

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FIGURES

1 INTRODUCTION

This report is the Final Report of iMOVE Project 3-008, Future Transport and Mobility Environment (FTME), which commenced in January 2020. The industry partner in this Project was the Queensland Department of Transport and Main Roads (TMR), and the research partners were the Australian Road Research Board (ARRB) and the iMOVE CRC, a Co-operative Research Centre established by the Australian government.

1.1 TRANSPORT AND TECHNOLOGY

In recent years, technology has enabled transport networks to deliver improvements in productivity, safety and efficiency through many different applications and services available to transport users and customers. There has also been an emergence in active and alternative mobility solutions (e.g., walking, cycling, scooters, working from home) as well as shared use business models (e.g., ride sharing, MaaS).

Transport and mobility are an eco-system that involves a combination of people, infrastructure and vehicles operating in a regulated environment that is more integrated because of technology and connectivity. Transport users today have an increasing number of travel options, while being informed of up-to-date travel time, modes, and costs. At the same time, there is a growing role for advanced technology and data solutions in operational planning and real-time operations.

As the transport and mobility environment becomes more integrated, this project looks to explore and challenge traditional approaches to transport operations and mobility. How do we move away from the way we do things today and think/act differently? The time horizon for the future transport and mobility environment envisaged is over the next 2-10 years.

1.2 CONTEXT

The main drivers behind this project were from the network operations/traffic management/ITS disciplines within TMR and ARRB. Some of the questions and thoughts were framed around:

1. How different would traffic management be if we started afresh today?
2. What are the key performance metrics to operate our networks today?
3. What are the infrastructure and operational impacts of the new technologies for networks?
4. What are the commonalities across transport authorities and service providers (core functional elements and operations)?
5. Managing across an integrated network with many mobility service providers
6. Customer expectations of safe and reliable journeys
7. Balancing supply and demand
8. Improving network performance
9. Challenges and opportunities with connected and automated vehicles
10. Sustainability, carbon emissions and electric and zero emission vehicles
11. Micro-mobility and active transport.

When we looked at the significant changes occurring in transport and mobility, the range of trials and demonstrations of technologies, and the rise of online digital platforms such as Uber that offer ride hailing services (the gig economy), we felt that it would be timely to revisit the conceptual vision of transport, much like understanding the forest from the trees. As each Australian state has developed their own portfolio of transport related projects, it was considered that a national perspective would be helpful in engagement and co-ordination.

As this report is being written, the unprecedented changes that are occurring to our everyday lives, because of COVID-19, serves to bring forward the possibility of these changes, enabling transport and mobility to be more integrated and resilient.

1.3 METHOD

This project commenced with an initial draft discussion paper which was intended as a ‘thought starter’ for engagement with 10 key stakeholders. Following feedback, a revised discussion paper was prepared, and feedback was received from 36 stakeholders across government transport authorities, industry and researchers via personal communications and a Survey Monkey questionnaire (Apr-May 2020). A report of the stakeholder feedback was prepared, and a Final Discussion Paper which included the stakeholder feedback was delivered (Karl & Cheong 2020). A webinar with a panel discussion was held on Sep 1, 2020, which attracted over 235 participants (Karl 2020).

These milestones have led to this Final Report. It is expected that the Final Discussion Paper will also be released at the same time as this Final Report.

1.4 FEEDBACK FROM STAKEHOLDERS

The main categories of the comments from the stakeholder engagements were in the areas of vision, leadership, stakeholders being busy with day to day work-loads, new challenges, fit with existing ITS architecture, as well as many stakeholders noting that we have the capabilities, testing sites and supporting infrastructure (Karl & Cheong 2020).

It is always more powerful to engage with experienced practitioners who can express the challenges, issues and experiences in their own words. The common themes of stakeholder feedback were:

1. Firstly, there is clearly a need of a fresh vision of the Future Transport and Mobility Environment which would enable a realignment of the goals and objectives of jurisdictions.
2. There is also a need for leadership to both develop this vision and then to develop the logical and physical layers.
3. Each jurisdiction appears to be going about it in their own way and it does not integrate well. Systems tended to be developed in house which do not work as technology is developing quicker and the old technology quickly becomes obsolete. Engagement with vendors right from the start is becoming more important.
4. It was recognised that most agencies are already busy with day-to-day work pressures and sufficient resources need to be allocated to this task.
5. There are several challenges in the Future Transport and Mobility Environment,
    a. stakeholders reported that they have the capabilities, having worked on similar projects in the past and already have some of the answers, structures, approaches and frameworks
    b. stakeholders commented that they have accumulated expertise and built knowledge in several trials and tests both in the past and in those underway in a number of jurisdictions, so that there was no need to be recreating the wheel
    c. stakeholders reported progress being made in the supporting infrastructure of the FTME, in terms of the soft infrastructure as well as the central and communications infrastructure
    d. to note that there are processes and channels already in place and that FTME needs to be aligned with these processes and channels.
6. The majority of stakeholders also noted that there was a strong team in architecture and have progressed with the National ITS Architecture and have developed regulatory and operational frameworks in a number of transport domains; traffic management, freight and logistics, CAVs, MaaS, digital platforms etc. which can be further streamlined into the logical and physical layers that will support FTME.

1.5 STRUCTURE OF THIS REPORT

This report is structured into five sections, Section 1 - Introduction, Section 2 - Vision, Section 3 - Roles, Section 4 - Pantry and Section 5 - Next Steps. It also contains an Appendix 1 which lists out a range of core functional elements contained in the Australian FTME pantry.

1.6 ABOUT ARRB

ARRB is the National Transport Research Organisation and is responsible for the delivery of infrastructure standards for State, Territory and Commonwealth Governments. ARRB was established 60 years ago and operates in all capital cities, with the headquarters in Melbourne. ARRB operates across six key strategic work groups that are listed below to service the Australian community.

1. Future Transport Infrastructure – what are our roads going to be made of in the future
2. Transport Safety – deliver a 50% reduction in fatal and serious injuries on our road system
3. Sustainability & Resilience – how do we keep communities connected and reduce our impact
4. Asset Management – how do we enhance the performance of the current road network
5. Future Transport Systems – how do we enable connected and autonomous vehicles to operate
6. Data Collection & Analysis – next generation intelligent data for road performance.

This project is led by the Future Transport Systems team with input from all six strategic work groups as well as from our leadership and the vision, concepts and roles have been presented and commented upon internally.

1.7 ACKNOWLEDGEMENTS

The authors wish to acknowledge the support of the project partners, TMR, ARRB and iMOVE for funding this project and providing invaluable support in leadership, guidance and wise advice whenever needed. Special acknowledgement of kind support and direction to Dennis Walsh and John Oppes from TMR and Dr Ian Christiansen and Jackie King from iMOVE.

We also deeply appreciate willingness and generosity of the key group of Australian experts and practitioners (who will remain anonymous) who were consulted as part of this project and provided input and critical feedback to the Discussion Paper during the time when COVID began to impact us.

Final thanks to Ted Beak as TMR Project Manager for keeping us on track and for our regular fortnightly meetings which ensured the project always having a clear direction.

2 VISION

This section develops the vision of a future transport and mobility environment.

2.1 BACKGROUND

Current transport systems and services have remained unchanged over a long period with slow incremental innovations as shown in Figure 2.1. These pictures from Manhattan show congestion in horses and carriages in 1900, followed by similar scenes of congestion by 1920 with the introduction of the motor car. One could imagine the early challenges faced by drivers in terms of fuel, and by regulators in terms of registration and driver licensing. Since that period, while cars are now more modern and equipped with significant technology, the traffic scene is relatively the same, albeit with ITS technologies such as signals, booking, despatching and payment systems in buses, taxis, delivery vehicles and trucks.

Figure 2.1: Land Transport changes over 120 years – Western example

While the existing road infrastructure and the vehicle assets will be around for some time to come, it will be in the ways we operate and integrate our infrastructure and vehicles that will be changed. There are concerns that legislation designed for different technical, commercial and social purposes are impeding the adoption of new products and services. For example, the rise of technology-enabled transportation services such as smartphone-based innovative mobility services often do not fit into existing regulatory structures (e.g. Uber and Lyft etc.). These services are expanding and have raised public policy issues such as:

- uneven regulatory playing field
- inconsistent requirement for incumbent taxis and emerging transportation network services
- equity implications of taxi industry decline
- public security
- employment status (Karl 2017).

There is renewed interest in travel demand management and network resilience in the light of customer expectations and societal changes driven by recent events such as COVID-19. These have added upon the efforts already underway in integration of the various state road agencies into the Departments of Transport and the integration of all transport modes in planning through to real-time operations.

In response to the possible future of transport and mobility, there have been a range of studies, strategic plans and reports by governments, industry associations and think tanks, especially over the last five years. A short listing of the various types of documents and reports is shown in Table 2-1.

A good example of the desired outcomes in the strategic transport plans typically place the customers first and express outcomes such as accessible and convenient transport, safe journeys for all, seamless, personalised journeys, efficient, reliable and productive transport for people and goods and sustainable, resilient and liveable communities.

Table 2-1: Examples of future transport industry plans, strategies and reports

Category	Country	Title
Transport	Australia	National Land Transport Technology Action Plan 2020-2023, Transport and Infrastructure Council (Canberra)
		Our Strategic Plan 2019-23, Department of Transport (Victoria)
		Future Transport Strategy 2056, Transport for New South Wales (NSW)
		Transport Strategy 2030, City of Melbourne
		Queensland Mobility Framework (Queensland Land Transport Technology Framework – QLTTF)
		Strategic Plan 2019-2023, Queensland Government
		Department of Transport Strategic Plan 2019-22, Transport WA
		Transport Strategy (Draft), City of Hobart
Zero Emission Vehicles	Australia	Advice on Automated and Zero Emissions Vehicles Infrastructure, Infrastructure Victoria
		Automated and Zero Emissions Vehicles | Transport Engineering Advice, Infrastructure Victoria
		ICT Infrastructure Advice for Automated and Zero Emission Vehicles, Infrastructure Victoria
Connected and Automated Vehicles	Australia	Future Transport 2056: Connected and Automated Vehicles Plan, Transport for New South Wales

2.2 INTELLIGENT TRANSPORT SYSTEMS

Intelligent Transport Systems or ITS is a term to describe a large collection of systems covering many areas of application in transport. In the early days, ITS mainly referred to traffic control with signals (1980s, SCATS, STREAMS, BLISS, SCOOT etc.) and expanded to include a range of dynamic traffic management and control systems (e.g. contra flow lanes, traffic advisory messaging, traveller information, compliance and enforcement and by 1999, the introduction of free flow tolling systems).

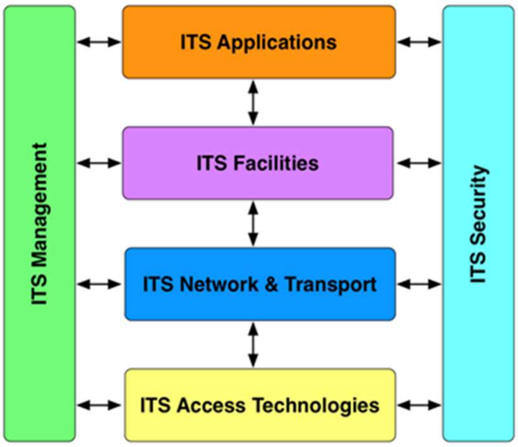
Since that time, there has been a huge development of many more areas emerging within the ITS domain as information and communication technologies advanced. At the 26th ITS World Congress held in Singapore last year (ITSWC 2019), 14,500 delegates attended and eight key ITS themes were covered:

1. Intelligent, Connected & Automated Vehicles
2. Crowdsourcing & Big Data Analytics
3. Sustainable Smart Cities
4. Multimodal Transport of People & Goods
5. Safety for Drivers & Vulnerable Users
6. Policies, Standards & Harmonisation
7. Innovative Pricing & Travel Demand Management
8. Cybersecurity & Data Privacy.

Intelligent transport systems (ITS) service domains and groups reflect the evolution of technology-oriented transportation practices and applications. While the scope of ITS has grown to cover technology in transport and mobility more broadly, the term ITS still has connotations of traffic signal and motorway technologies, highlighting the need for common language. As such, attempts at harmonisation and standardisation in ITS are critical. By 2010, an ITS station concept was developed by the International Standards Organisation (ISO 21217: Communications Access for Land Mobiles (CALM) – Architecture).

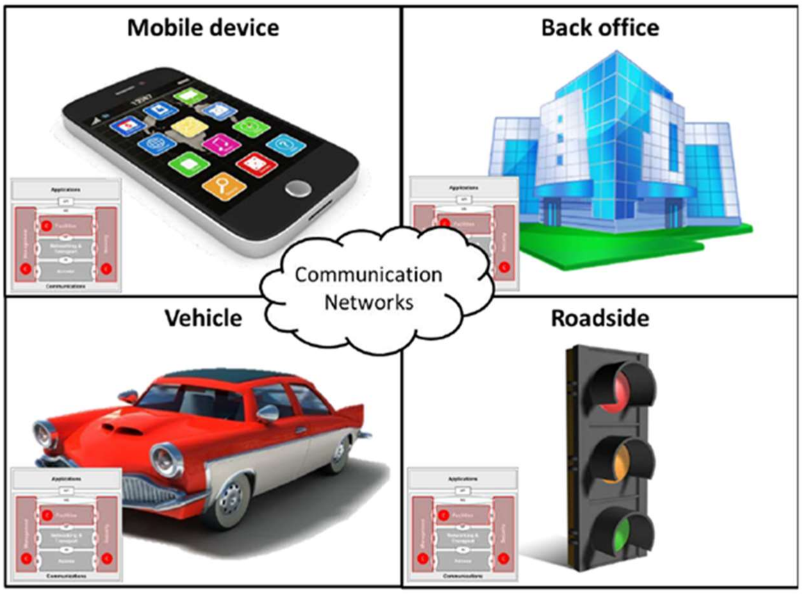
This international standard specified the minimum set of normative requirements for a physical instantiation of the ITS station as shown in Figure 2.2, which included application, facilities, network & transport, and access technologies supported by management and security layers.

Figure 2.2: ISO station concept (ISO 21217)



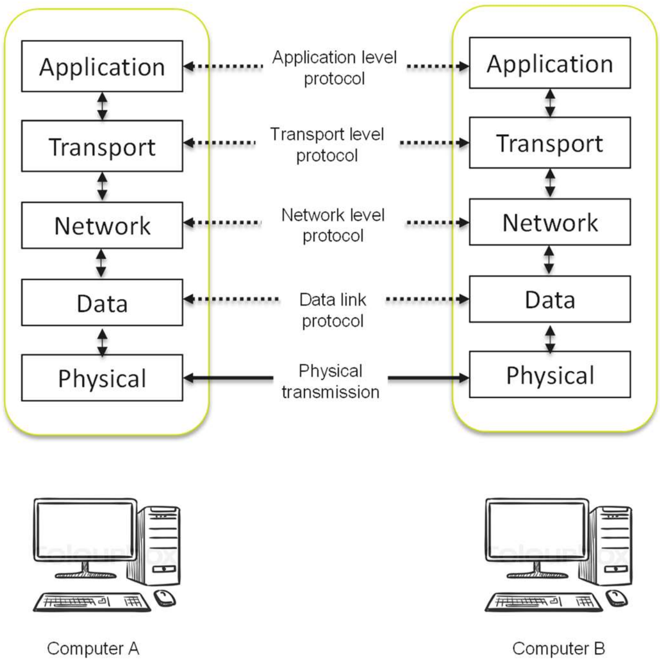
A physical view of ISO 21217 is shown Figure 2.3. By standardisation of the ITS station concept, it is possible to appreciate various instantiations of ITS stations in devices at the roadside, in-vehicle, at the back office and used as personal handheld nomadic devices operating within an ecosystem where communications, integration and interoperability is enabled via adherence to standards, common definitions and roles and responsibilities made explicit.

Figure 2.3: Physical representation of ISO station concept



It is important to note that the 2010 ITS station architecture concept developed by ISO was originally based on the Open System Interconnection model developed in 1984, as shown in Figure 2.4, to support the interactions of computers with other computers (OSI stack, ISO/IEC 7498-1).

Figure 2.4: OSI stack (circa 1984)

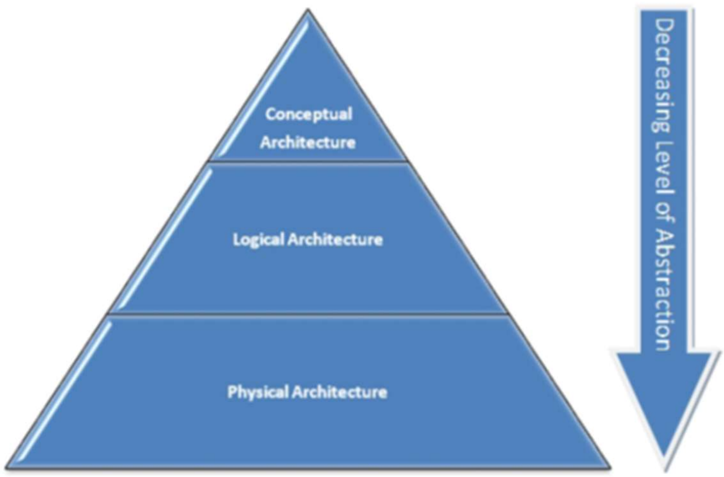


The traditional ITS systems from the 1980s are changing to modern ITS systems architected to technology architectures such as ISO 21217 standards, based on a layered approach and regulated and operated by actors in roles and responsibilities within a new system concept of operations.

2.3 SYSTEMS ARCHITECTURE

Intelligent transport systems need to integrate in a system that delivers a safe, efficient, sustainable and productive environment for transport and mobility. A typical systems architecture provides three views at decreasing levels of abstraction as shown in Figure 2.5 (Austroads 2014a). These three layers are the conceptual, logical and physical architecture layers. The conceptual layer is a highly abstracted view of the system with the most significant components or entities. The conceptual view provides a high-level understanding of the system's purpose or objective which should be clear and concise, thereby supporting communication and comparison with other concepts.

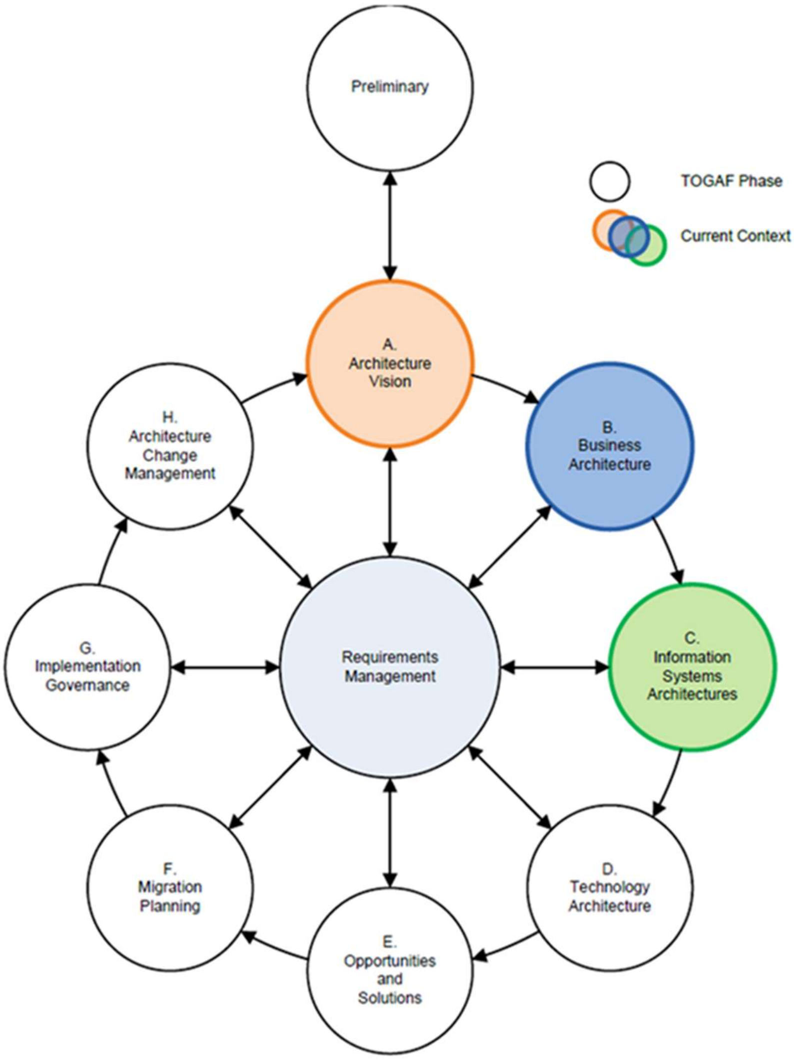
Figure 2.5: Systems engineering architecture



The logical layer is more detailed and incorporates all the major system components or entities and the relationships that exist between them. The purpose of the logical architecture is to ensure that all the components are captured and described, that the relationships between the components are specified and that the information that will be exchanged between components is detailed. Finally, the physical layer is the most detailed and provides the detailed specifications required to build and implement the system.

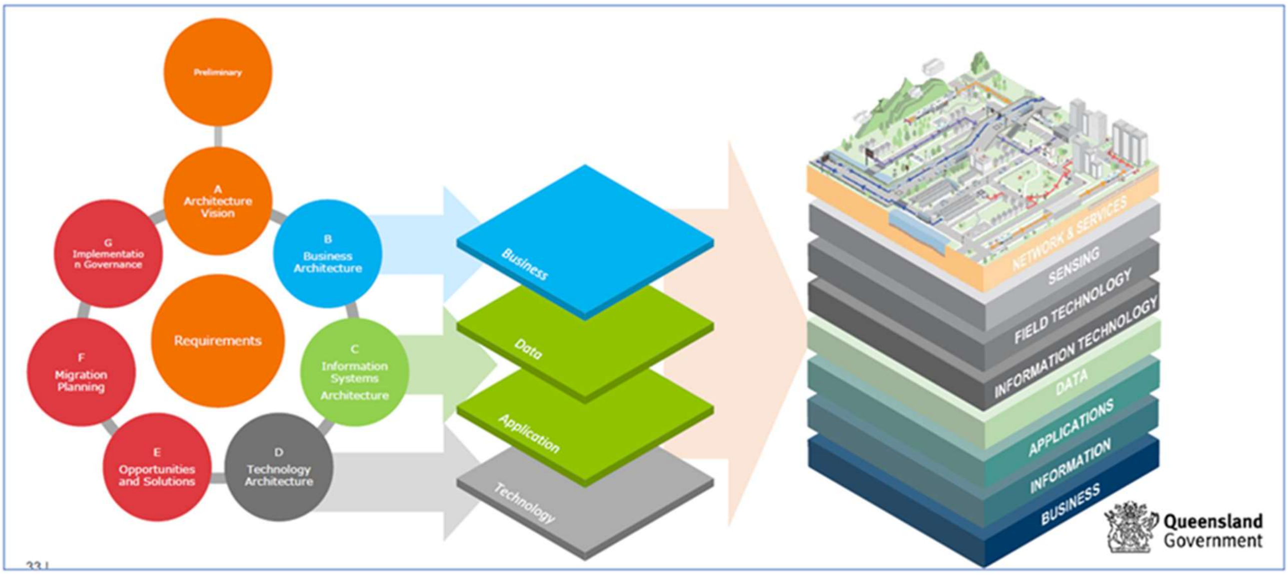
The Australian National ITS Architecture (NIA) has adopted The Open Group Architecture Framework (TOGAF) as its base (Austroads 2016). The architectural development methodology for TOGAF is outlined in Figure 2.6 (Austroads 2017). It steps through a process which starts with an architectural vision (A) followed by the business architecture (B), information systems architectures (C), technology architecture (D) and so on.

Figure 2.6: TOGAF architecture development method



The alignment of the National ITS Architecture can be seen with the Queensland Land Transport Technology Framework as shown in Figure 2.7 (TMR 2019). The layered QLTTF contains business, data, application, and technology layers that align with the TOGAF architecture development method.

Figure 2.7: Alignment between NIA and QLTTF



2.4 CONCEPT OF THE FUTURE

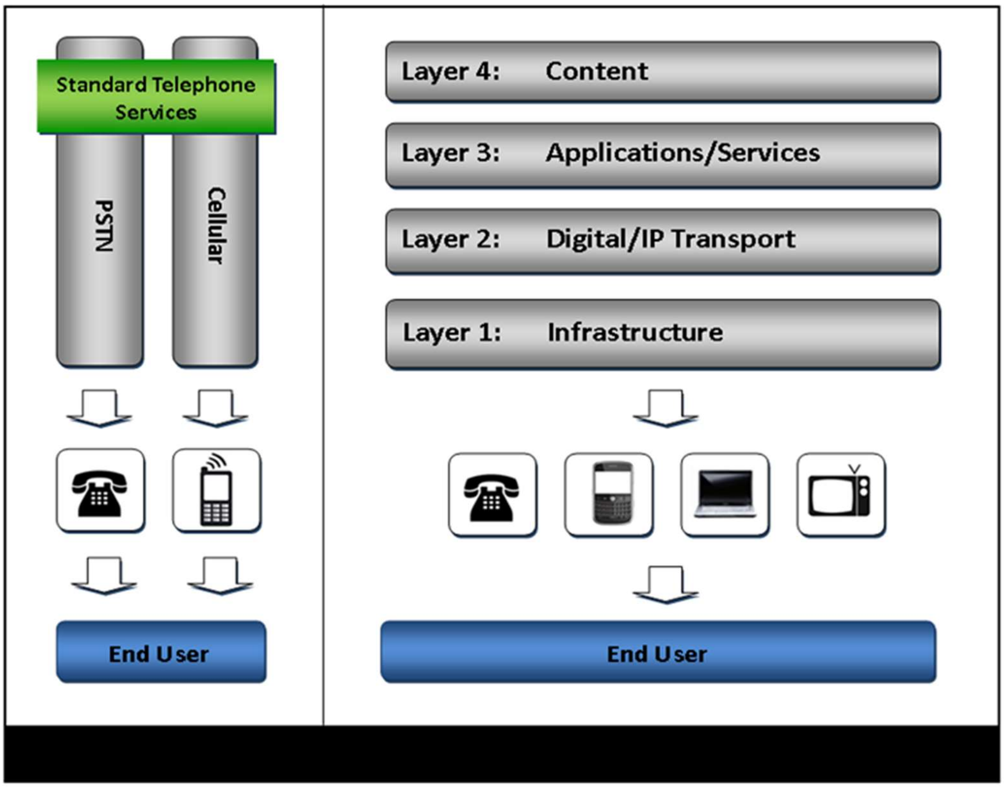
This section develops a conceptual future transport and mobility environment based upon the systems architecture approach of the previous section.

A decade ago, the telecommunications sector faced the same challenges that the transportation sector faces today. This is not surprising as both domains are impacted by the same technology (digitisation and connectivity). In 2011, the Australian Communications and Media Authority (ACMA) reported the changes the communications sector were experiencing in their legislative landscape as shown in Figure 2.8. ACMA described the situation as follows:

In communications, "*legacy delivery arrangements followed service-specific networks and devices. Technological change in the form of digital transmission systems means that service delivery is now largely independent of network technologies. This can be conceived and depicted as a shift from the vertical, sector-specific approach to the horizontal, layered approach. One important consequence of this change is that regulation constructed on the premise that content could (and should) be controlled by how it is delivered is losing its force, both in logic and in practice. In practical ways, this is affecting the day-to-day work of the regulator in administering legislation and applying these concepts to innovative services and delivery mechanisms that were not envisaged at the time existing core legislation was enacted.*"
(p2-3 executive summary, ACMA 2011)

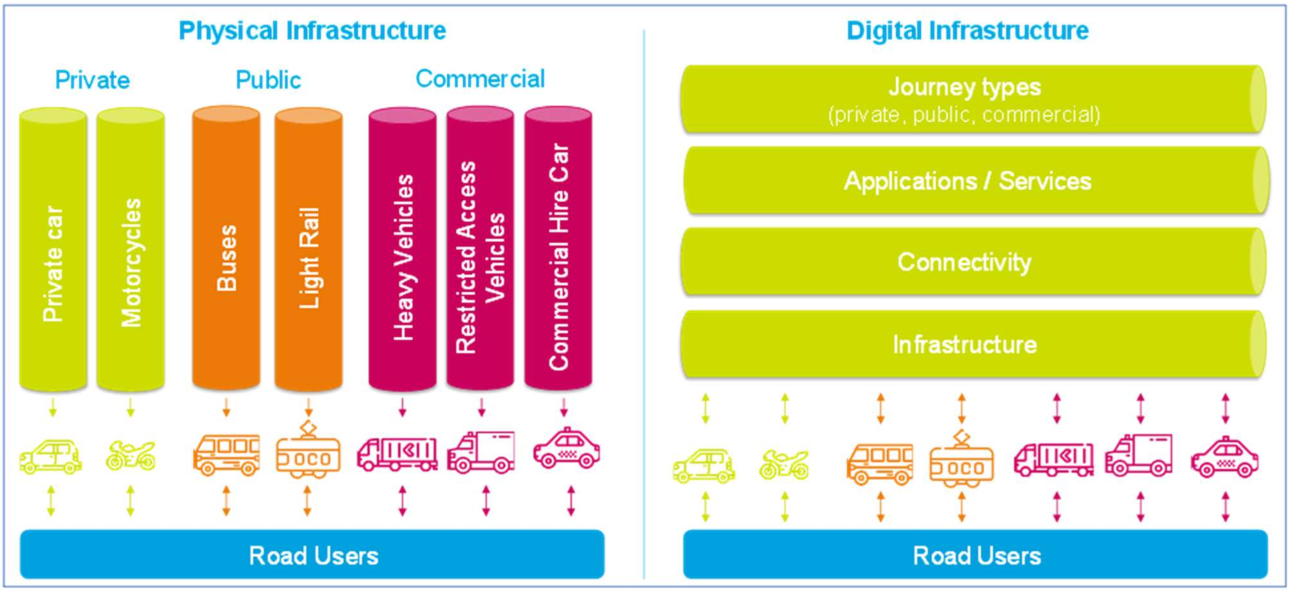
The silo based view of the communications sector based on fixed line and cellular architectures shifted to a layer based view of the communications environment, which comprised of content, application, transport and infrastructure layers.

Figure 2.8: Convergence in networks and service layers (ACMA)



A similar approach for transport could possibly be represented in the figure we developed below, Figure 2.9. The current silos in land transport associated with private vehicles, commercial vehicles and public transport (road and rail) are now beginning to change whereby service delivery is largely independent of the specific transport silo. A car can be a private vehicle, a service, commercial or freight vehicle and a public transport vehicle all in the same 24 hours. Journeys (or mobility) are enabled by applications and services provided by Service Providers and supported by layers of digital and physical infrastructures.

Figure 2.9: Convergence in networks and service layers (ARRB version)



In essence, digital infrastructure has been rolled out across the physical infrastructure of the land transport network. The change in thinking from a silo based view to a layer based view of the future transport and mobility ecosystem requires alignment of technology and innovation with the other key elements of a system; policy and legislation, infrastructure and people.

3 ROLES

In harmony with the vision, the actors in that environment will need to smoothly interact and transact with each other. The vehicles, the infrastructure, the users and the regulatory and operational frameworks work together to deliver the desired outcomes. Roles and responsibilities of the actors require definition and clarity, and this section develops a conceptual model of the roles and responsibilities within a future transport and mobility environment.

3.1 MOBILITY INTEGRATION

Mobility will be one of the biggest driver of economies in the next decade. Innovative mobility services are expanding travel choices and are being widely embraced by millions of drivers. Shared mobility services have the potential to change our long-term travel patterns. However, providing mobility-as-a-service is never easy for any single player as mobility needs to combine everything from public transport, car ownership, rental and sharing to payment flexibility, system interoperability, public security, disparity between access for users with disabilities and other travellers etc. Increasingly, private sector service providers are keen to work with governments and become more involved in policy, standards and regulation processes.

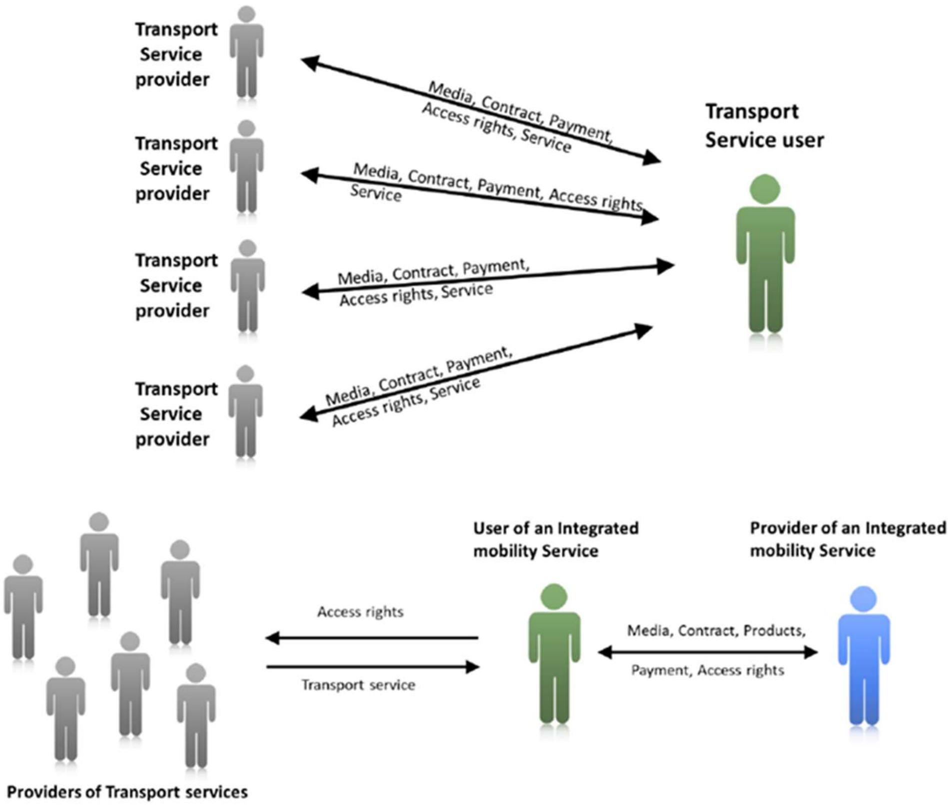
The travel of a person or goods often requires the use of a range of transport services from differerent providers in the one trip. For example, a traveller going to work may drive to a nearby train station, take the train to a bus stop, from which they will make the last trip by bus to the office. This chain of transport services requires different explicit or implict contracts between the traveller and providers, different media having access rights to the service, as well as different payment methods.

Following the completion of standards development for 5.9 GHz C-ITS in 2016, the European Union began to initiate a new suite of standardisation activities in Integrated Mobility starting in 2018, and in the same year a joint working group of CEN TC278 (WG17) and ISO TC204 (WG19) was established to co-ordinate EU standardisation with ISO standardisation. Among the work items, two deliverables of relevance are (i) ISO TR 4447 Integrated Mobility Concept (ISO TR 4447) and (ii) ISO TR 4445 Role Model of ITS Service Application (ISO TR 4445).

The CEN/ISO Integrated Mobility Service Concept is shown in Figure 3.1 (ISO TR 4447a) depicting the relationships and key functions between users and the service providers. In the top half of the figure, a transport service user typically has contracts and deals with a range of transport service providers. A typical trip may involve travelling on a bus to a train station and finally a tram or short bus ride to the final destination. In other cases, it may also include e-scooters or e-bikes, ride sharing or ride hailing services.

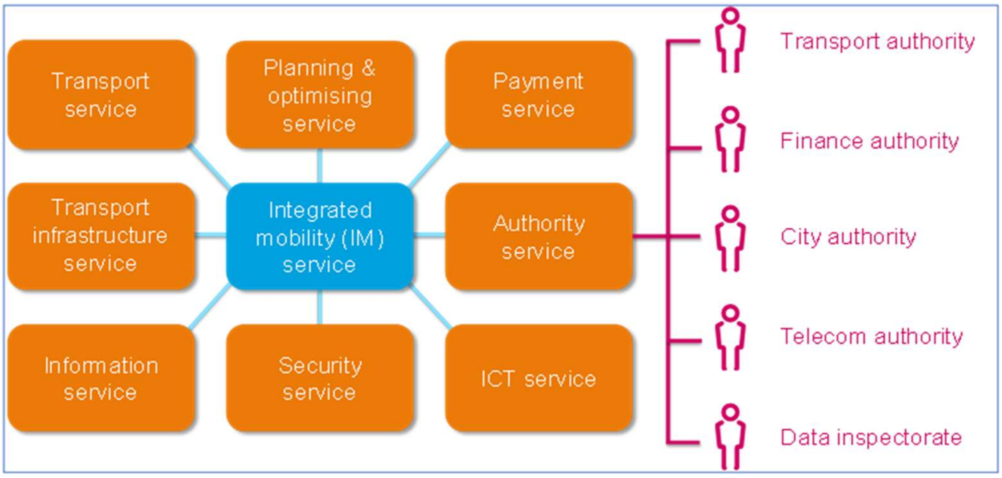
The main objective of integrated mobility is to enable travellers or goods to benefit from a seamless and optimised travel from A to B in a multimodal and multiservice provider environment (ISO TR 4447a). This can be achieved by the traveller or the goods sender/receiver having one contract and one payment interface with an entity that bundles the requested transport services in a package, as shown in the lower half of the figure. Through a single contract with a service provider, the user, customer/traveller has access to a range of transport services.

Figure 3.1: One to many relationships in an integrated mobility service



The integrated mobility service builds and is dependent on other services as shown in Figure 3.2. In addition to services such as journey planning, information, payment and other services, the interface with authority services is also streamlined as shown on the right hand side of the figure.

Figure 3.2: Main services in an integrated mobility service



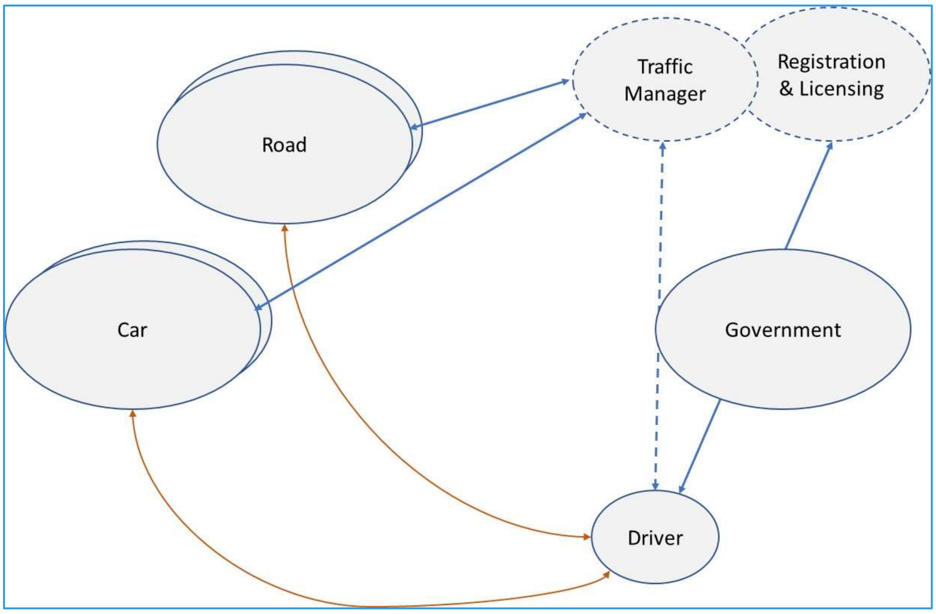
3.2 ROLES AND RESPONSIBILITIES

Having described the actors in the transport ecosystem, this section develops the role and responsibility model of the future transport system. The key actors in the ecosystem are distributed in three layers:

1. Core Business – the customer / user, the service providers, and the transport operators
2. Extended Enterprise – the technical backend providers, payment solutions providers, data providers, journey planners, the information and communications infrastructure and other elements
3. Business Ecosystem – the regulators, the investors, the network operators, researchers and other stakeholders (e.g., unions, media, etc).

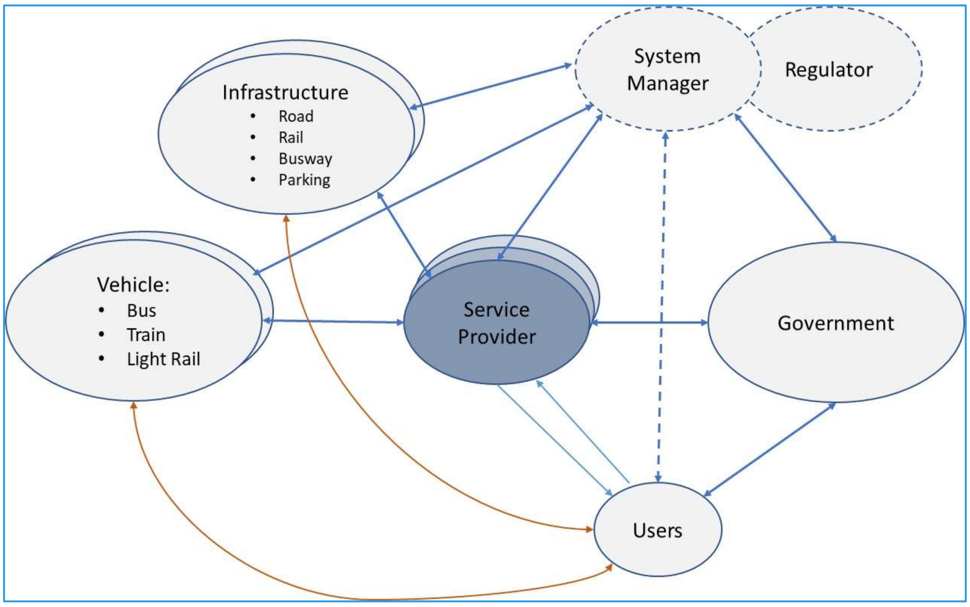
An example of the role and responsibility model applied to private vehicles is shown in Figure 3.3 below. The driver purchases a car and operates the vehicle on a series of roads going from home to work. To undertake such a journey, the driver must have a driver's licence and the vehicle needs to be registered by the local government. When driving on the road, the driver must obey the road rules and traffic management practices (such as signals, lane management controls) to ensure safety and efficiency with other road users. There are of course many other actors in this simple model, such as the police and emergency services, travel information providers, toll road operators, parking operators, mechanics, crash repair businesses, car rental agencies, insurers and finance companies just to name a few. Together the actors form the overall transport ecosystem.

Figure 3.3: Role and Responsibility in private travel



Following the same format, a simplified role and responsibility model of public and commercial transport is shown in Figure 3.4 below. A transport user or customer travels from A to B via a taxi, bus, tram, train, ferry or via a mobility service provider (e.g. Uber, GoGet, etc.). In the public and commercial transport ecosystem, the actors in the model increases but the core roles and responsibilities remain with the addition of a new actor, the Service Provider. The Service Provider definition includes both the traditional public transport service providers as well as the new mobility service providers.

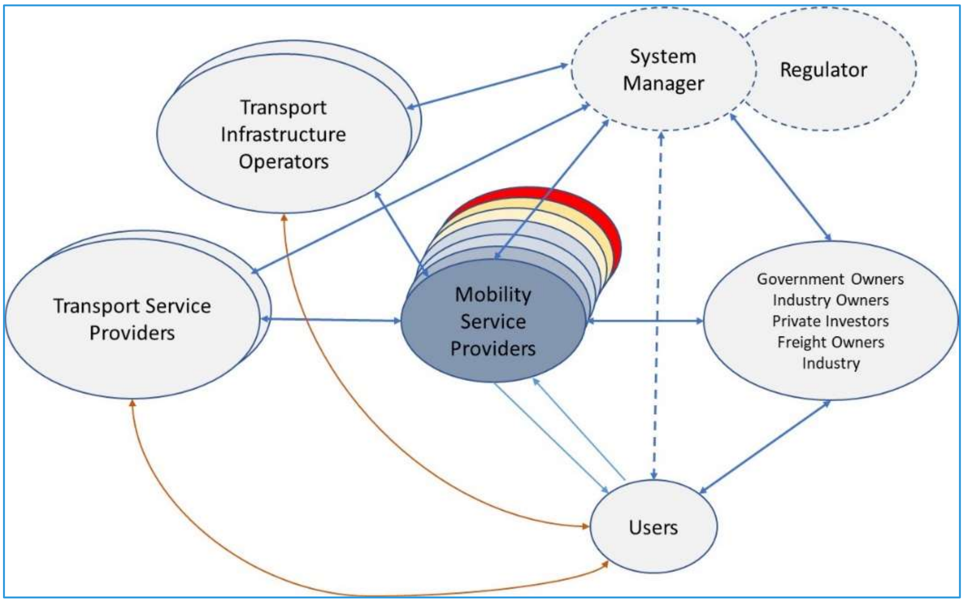
Figure 3.4: Role and responsibility in public and commercial transport



Flowing from an understanding of the role and responsibility model in today's transport and mobility environment, a possible future integrated FMTE role and responsibility model is presented in Figure 3.5. In this figure, the actors who are now defined as 'Mobility Service Providers' have increased in number as well as in the types of mobility services they offer to users, ranging from the traditional public transport services to a broad spectrum of services including journey planning, concierge, click and collect, payments, micro-mobility, journey planning, ride-sharing, ride-hailing and even robots and drones.

The actors who own and operate road, rail, bus, parking and other land transport infrastructure are covered under the definition 'Transport Infrastructure Operators', while the actors with vehicles such as the cars, buses, trains, trams, bicycles, scooters and drones are defined as 'Transport Service Providers'.

Figure 3.5: Future transport role and responsibility model



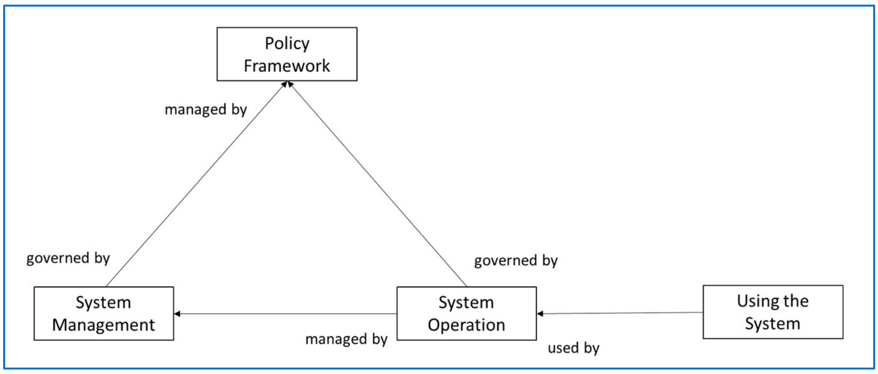
Other actors as shown in the above figure include; (i) 'Users' who could be drivers, other road users and customers, (ii) 'Owners' which could include all levels of government, industry, investors and the community, and (iii) the 'System Manager' and the 'Regulator' who are the actors who operate and regulate the transport and mobility environment.

The development of the integrated mobility concept is currently under development by ISO TC204 WG19 as ISO Technical Report 4447 Integrated Mobility Concept V2 which is at a working draft stage (ISO TR 4447b, ISO TC204/WG19 N244, 2020). At its present stage, it is focussed on merging the European MaaS concept with the US Mobility on Demand concept.

In these documents, the System Manager has yet to be defined and currently falls under the actor named as 'Regulator'. There is little definition in ISO work on the concept of the System Manager. In the land transport space, stakeholders have a better understanding of the role of a system manager in terms of three key areas; in (i) asset management, (ii) operations management and (iii) safety. This applies to the road and rail network especially in terms of traffic management centres, safety agencies, supporting compliance and enforcement activities and emergency services.

ISO 17427 Roles and Responsibilities in the context of co-operative ITS (ISO TS17427) is one of the few documents which identifies system management as shown in Figure 3.6. In this figure, users operate within a system that is governed by a policy framework (Regulator) and managed by a System Manager. Other terms used to describe "System Manager' include: network manager, network steward, and system orchestrator. It is noted that while the roles and responsibilities of road system manager and the rail system manager are well established, this study has found little or nothing at all on the roles and responsibilities of the integrated mobility System Manager.

Figure 3.6: Role of System Manager



For further clarity, a list of the key actors, and their roles and responsibilities are shown in Table 3-1.

Table 3-1: Key roles and responsibilities

Role name	Responsibilities	Comment
Mobility Service Provider (MaaS Provider)	Manage transport service offers from transport service providers Define and provide mobility services to a Mobility Service User based on service request and user profile and preferences	The Mobility Service Provider describes how the service shall be used, how the service shall be paid for and how the income for a service shall be shared between the involved stakeholders
Mobility Service User (Customer)	Define and send a mobility service request to the Mobility Service Provider using the user profile and preferences Receive the access rights to the mobility service and use the service in line with the service terms and conditions and pay for it	Could be the '*passenger*' in a bus or the '*rider'* on an e-mobility scooter or the '*driver*' in a shared vehicle
Transport Service Provider (Transport Operator)	Provide a scheduled or on-demand transport service to a user	Could also be public transit agencies, logistics service providers
Payment Service Provider	Enable a user to pay for a mobility service that will be used, is being used or that has been used	
Transport Infrastructure Operator	Build, operate and maintain the transport infrastructure needed by a Transport Service Provider for the provision of the transport service	e.g. a road authority operating a road network with dedicated bus lanes and traffic signal priority requested by a public transport operator
Regulator (Policy Makers)	Enable and facilitate the provision and use of mobility services through policy, legal and specification frameworks	Federal, State and Local authorities are examples of instances of the Regulator role
System Manager	Monitor implementation and operations of mobility service schemes	
Owners	Ownership of the actors, all levels of Governments, investors, industry, freight industry, community	

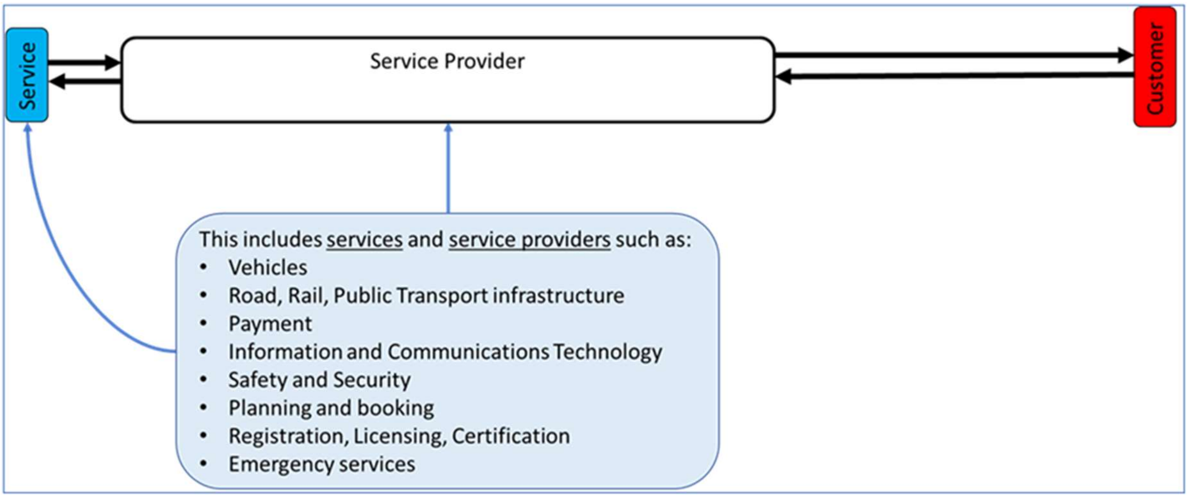
4 PANTRY

This section develops an understanding of the core functional elements in FTME. These core elements are common across many of the systems in integrated mobility and can be thought of as the ‘pantry’ which contains the developing and development core components of FTME.

4.1 CONCEPTUAL MODEL

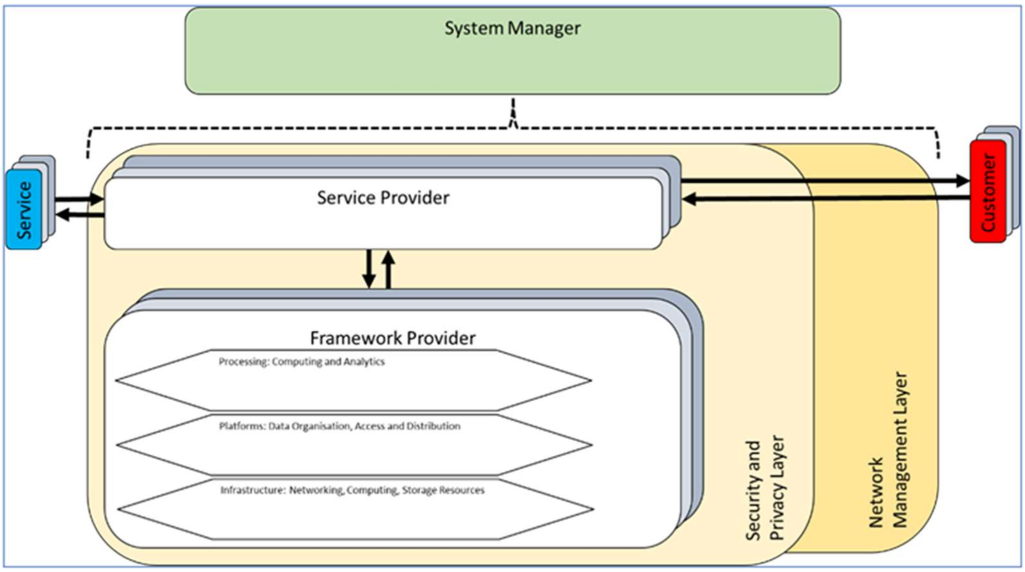
We will now commence to develop a conceptual model to provide a clear view of the core functional elements. Figure 4.1 represents a single service provider delivering a service to a customer. The service could involve vehicles, different transport networks (road, rail, etc.), traveller information, MaaS, and so on.

Figure 4.1: Basic Service Provision



For the Service Provider to deliver the Service, the Service Provider requires a business system which has technology in the form of infrastructure, platforms and processing capabilities, supported by security, privacy and management layers. The Service Provider establishes a system sourced from technology vendors to provide hardware, software, storage, analytics and other requirements for an in-house operation or as a service as shown in Figure 4.2. This figure depicts several Service Providers operating in a system managed by a System Manager.

Figure 4.2: Basic Service Provider Conceptual Model



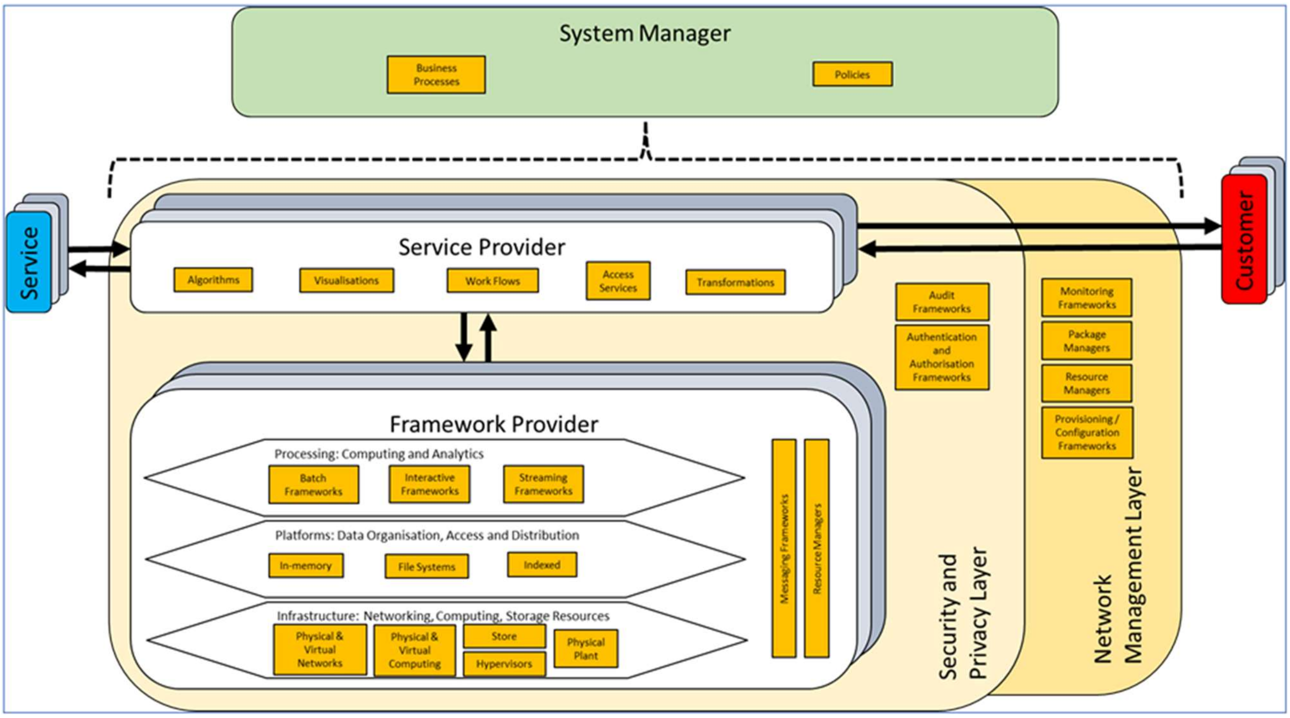
This model was based on the conceptual model used in a recent PIARC report on Big Data for Road Network Operations (PIARC 2019) and reported in the Final Discussion Paper (Karl & Cheong 2020).

4.2 FUNCTIONAL COMPONENTS

The functional component view of the conceptual model defines and describes the functional components (e.g. hardware, software, people, organisations) that are required for the system to operate. Figure 4.3 shows common classes of functional components in each layer of the model.

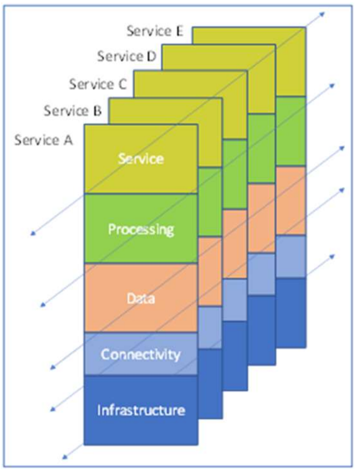
In the figure, the System Manager has core functional components such as business processes and policies. The Service Provider also has business processes and services supported by the technology platform which has infrastructure such as networking, computing and storage, enabling data processing and analytics and integrated with security, privacy and network management layers.

Figure 4.3: Common Classes of Functional Components



When a view of the key functional components is taken across a range of FTME services (e.g., Service A to Service E) as shown in Figure 4.4, then the common core functional elements such as processing, data, connectivity and infrastructure can be better identified. Identifying the core elements helps in (i) making us aware of what we already have, (ii) what needs to be developed further and (iii) what is missing.

Figure 4.4: Component view across various FTME services



In an earlier stage of this project, some examples of core functional elements of the actors in the Conceptual Model were identified and are listed below in Table 4-1.

Table 4-1: Core functions (Karl & Cheong 2020)

Role in Conceptual Model	Common functional elements
System Manager	Regulatory policy Operational framework Certification Safety Assurance Whole of network monitoring and optimisation Compliance and enforcement Registry and credential management National interoperability and consistency
Service Provider	Applications, processes, analytics, business systems Infrastructure Assets Connectivity Positioning Safety Assurance
Framework Provider	Hardware Software Assets Storage (Cloud) Connectivity Positioning Sensors
Security and Privacy	Secure exchange of data Trust and integrity of data Assurance of privacy Facilitation of a platform for sharing Misbehaviour management
Network Management	Standards Protocols Monitoring Package management

Further work was undertaken to develop a more comprehensive listing of the core functional elements in FTME to gain an appreciation of the depth and breadth of the functional elements already present in Australia. The full listing of the functional elements is attached in Appendix 1 and depicted in Figure 4.5.

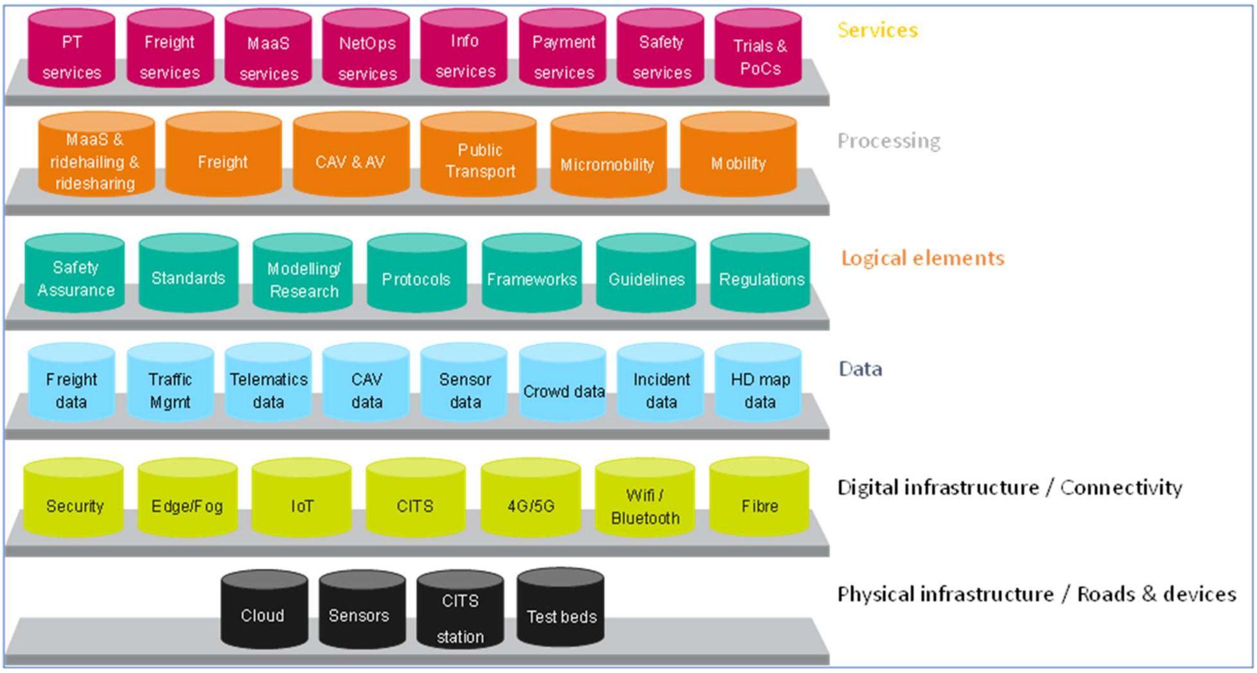
In this first version of the pantry, the pantry of functional elements has been layered into six layers:

1. Services – the range of mobility services available from specific service providers and transport and mobility operators.
2. Processing – the integration and transformation of data and logical elements into business specific requirements for actors in the transport and mobility ecosystem.
3. Logical elements – the regulatory, operational and safety frameworks that enable safe and efficient operations of the transport and mobility ecosystem.
4. Data – the data required for users, service providers and regulators who operate in the ecosystem.
5. Digital infrastructure and connectivity – the infrastructure that provides the connectivity layer between the customers, the vehicles, the infrastructure and the back offices of the ecosystem.

6. Physical infrastructure / roads and devices – the infrastructure and technology that comprise the roads, rail and supporting assets including ITS on which the land transport network is based.

The listing is really a living and ever-expanding part of the future transport and mobility environment and it is intended to continue to maintain the list online, in a part of the Future Transport Systems webpage on the ARRB website after this project is finalised.

Figure 4.5: Core functional elements



5 NEXT STEPS

The project undertook an investigation to explore and challenge our traditional approaches to transport operations and mobility in the face of new technologies and communications enabling greater integration of transport and mobility. This section considers the next steps following from this report.

5.1 ALIGNMENT WITH OTHER WORK

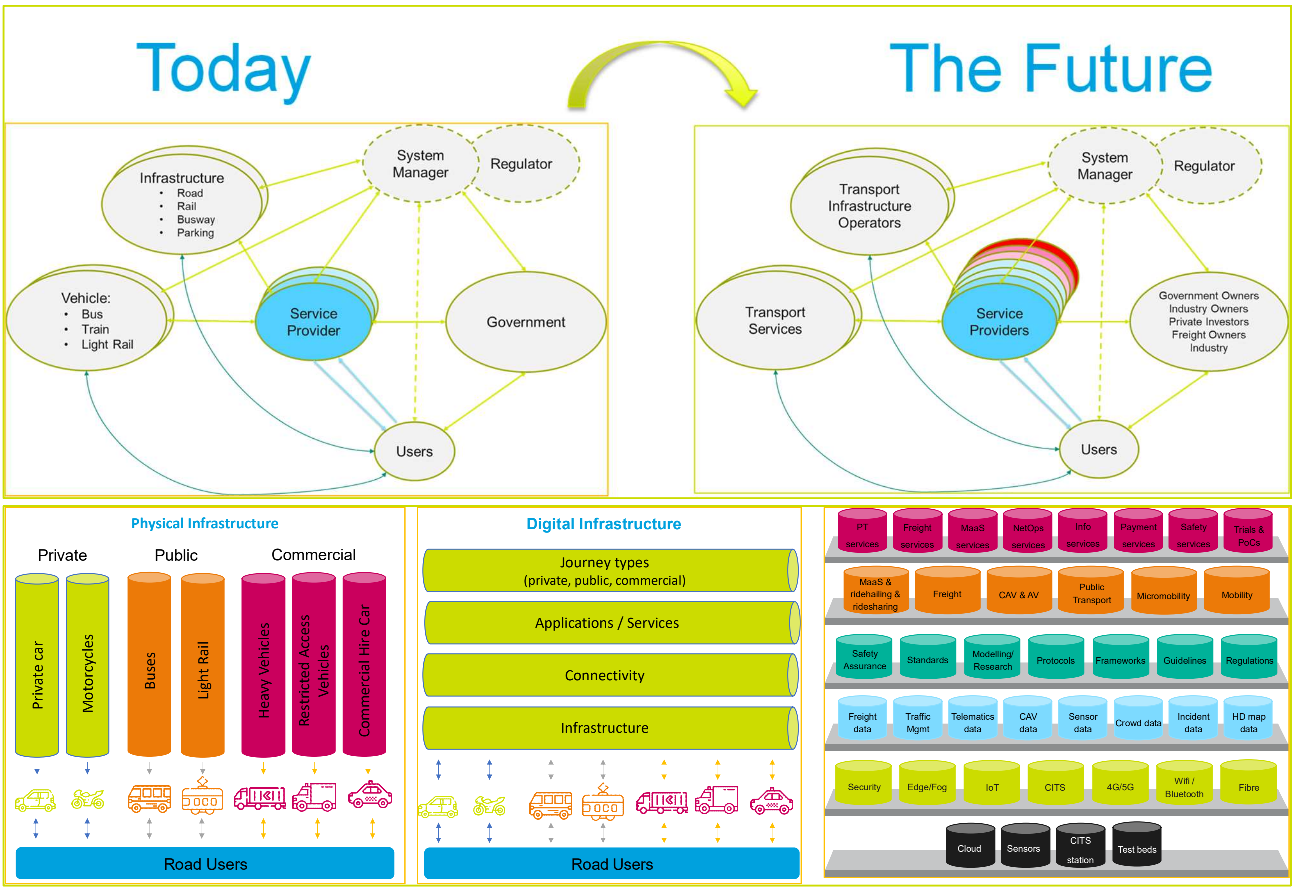
The findings of this project can be summarised in Figure 5.1 which shows (i) the physical and digital infrastructure and (ii) the pantry of core functional elements, in the lower half of the figure, and (iii) the roles and responsibilities, in the top half of the figure.

The physical infrastructure of transport and mobility has been complemented by digital infrastructure and better connectivity between people, vehicles, infrastructure and back offices. The Australian ‘pantry’ of core functional elements continues to expand and mature and these functional elements are utilised by the actors in the future transport and mobility environment in roles such as Service Providers, Transport Services, Transport Infrastructure Operators, Customers and Users as well as Governments as Regulators and System Managers.

While the roles and responsibilities today and in the future look similar, the increasingly integrated nature of transport and mobility calls for a fresh definition of roles and responsibilities of actors such as the System Manager and Regulator which is currently fragmented across a number of actors in roads, heavy vehicles, public transport and freight.

Further consideration and refinement of the FTME concept and roles among the stakeholders leading to a broad in-principle agreement would be helpful as it defines the forest from the trees, and provides a sound context for alignment with other programs and projects.

Figure 5.1: Transport and Mobility – Today and the future



5.2 DEPLOYING LARGER VISION

The development of a clear understanding around the conceptual and functional areas of a future transport and mobility ecosystem provides the opportunity to disseminate this knowledge to other areas outside of transport, for example to:

1. Aviation – for integration with airside services related to drone operations
2. Defence – for integration with land transport movements by Defence
3. Freight – for integration with national supply chains
4. Big data – for better integration with national and state initiatives associated with data hubs, data exchanges, national interest data sets, data custodians etc.
5. Safety – for better integration and harmonisation across safety assurance policy and frameworks across land transport modes including mining, agriculture, defence as well as aviation (in terms of drones)
6. Research – for better understanding and integration of research funding across a range of transport and industry sectors
7. Robotics and automation and autonomy – for better understanding and integration and alignment of technological developments by industry
8. Telecommunications and Spectrum management – for better understanding and alignment of telecommunications and spectrum allocations
9. Standards Development Organisations – for better understanding and integration of standards development activities across domains not only in Australia/New Zealand but also internationally.

In doing so, several consulted stakeholders commented that it would result in a larger overall FTME vision and also inform other domains as they develop their own visions and concepts.

5.3 DISSEMINATION

Subject to approval by the project partners, it is the intention that this Final Report and the accompanying Final Discussion Paper will be made publicly available. It is also planned that a further information dissemination activity such as a webinar be delivered in early 2021 with the possibility of further knowledge sharing activities through other groups such as iMOVE, Austroads and ITS Australia, and through papers and conferences.

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APPENDIX 1 – AUSTRALIAN PANTRY

Table 1 - Freight

Coordinator	Projects (Freight)	Physical infrastructure	Digital infrastructure	Data	Logical elements	Processing	Services
iMOVE-Industry-University	Freight data requirements (2-005)			Freight data	Framework	Freight	Freight services
	Mapping passive railway crossings to inform freight potential (1-015)			Maps		Freight	Freight services
	Co-modality: making use of public transport to carry freight (2-003)					Maas/Freight	Freight services/ Trial
	Freight consignment data aggregation pilot (2-008)			Freight data		Freight	Freight services/ Trial
	Evaluating loading dock capacity (2-010)					Freight	Freight services
iMOVE-University	Transformative commercial urban delivery solutions (5-008)					Freight	Freight services
	Risk in blockchain integrated container shipping systems (5-018)		IoT	Freight data		Freight	Freight services
	Fixed-wing drones and small package delivery (5-021)					Freight	Freight services
	Real-time data to preserve Aussie berries in transit (5-012)		IoT	Freight data		Freight	Freight services
	Optimising Loading/unloading freight bays (5-015)					Freight	Freight services
Austroads	Framework and tools for road freight access decisions (AP-R629-20)				Framework	Freight	Freight/NetOps services
	Harmonisation of measurement and mass assessment procedures for special purpose vehicles (AP-R632-20)				Guideline	Freight	Freight/NetOps services
	Heavy vehicle usage data project (AP-R602-19)			Telematics/freight data		Freight	Freight/NetOps services/ Trial
	Guideline for provision of heavy vehicle rest area facilities (AP-R591-19)				Guideline	Freight	Freight/NetOps services

Coordinator	Projects (Freight)	Physical infrastructure	Digital infrastructure	Data	Logical elements	Processing	Services
	Establishing extended hours delivery trial (AP-R586-18)				Trial	Freight	Freight/NetOps services/ Trial
	Local road access for high productivity freight vehicles (AP-R559-18)				Guideline	Freight	Freight/NetOps services
	Development of national mass assessment procedures for oversize over-mass vehicles (AP-R555-17)				Framework	Freight	Freight/NetOps services
	Improved railway road design for heavy vehicles (AP-R549-17)				Guideline	Freight	Freight/NetOps services
	End-to-end supply chain visibility (AP-R538-17)	Sensors	IoT	Sensor data	Guideline	Freight	Freight services/ Trial
	Community service obligations framework for the roads sector (AP-R545-17)				Framework	Freight	Freight/NetOps services
	Reassessment of the benefits and impacts of the use of high productivity vehicles on Australian highway pavements (AP-R541-17)				Framework	Freight	Freight/NetOps services
	Developing braking standards for heavy vehicles to brake effectively and safely on steep declines (AP-R539-17)				Standard	Freight	Freight/NetOps services
	Identification of a risk indicator to support Life-line freight routes (AP-R525-16)				Framework	Freight	Freight/NetOps services
	National Strategic weigh-in-motion network (AP-R535-16)				Framework	Freight	Freight/NetOps services
	Freight movement in emergency (AP-R521-16)				Guideline	Freight	Freight services
	National steer axle mass limit (AP-R505-16)				Regulation	Freight	Freight services
NTC	Australian dangerous goods code				Regulations/standards	Freight	Freight services
	Load Restraint Guide for heavy vehicles				Guideline/ Safety assurance	Freight	Safety/freight services
	Heavy vehicle national law (HVNL) - General - Fatigue management - Mass, dimension, and loading - Vehicle standards				Regulations	Freight	Freight/NetOps services

Coordinator	Projects (Freight)	Physical infrastructure	Digital infrastructure	Data	Logical elements	Processing	Services
	Heavy Vehicle National Law (HVNL) review				Framework/ Safety assurance	Freight	Safety services
	Heavy vehicle driver fatigue data framework			Freight data	Framework		Info services
	Heavy vehicle charges model law				Regulations	Freight	Freight/NetOps services
	Australian light vehicle standards rules				Standards	Freight	Freight/NetOps services
	Road user charges				Standards	Freight	Freight/NetOps services
DITRDC	National heavy vehicle charging pilot		IoT	Telematics data		Freight	Freight/info services/ Trial
	Financial policy elements of developing a forward-looking cost base for heavy vehicle charging				Research	Freight	Freight/NetOps services
	Economic analysis of potential end-states for the heavy vehicle road reform				Research	Freight	Freight/NetOps services
	Price regulation of heavy vehicle charges - Heavy vehicle road reform road map				Regulations	Freight	Freight/NetOps services
TCA	Intelligent Access Program	Sensors	4G	Telematics data	Regulations	Freight	Freight/NetOps services
	On-Board Mass Monitoring	Sensors	4G	Telematics data	Regulations	Freight	Freight/NetOps services
NHVR	Electronic Work Diary Standards			Telematicss data	Regulation	Freight	Freight/NetOps services
	Enterprise Information Management Framework				Framework	Freight	Freight services

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Table 2 - Connected and Automated Vehicles (CAVs and AVs)

Coordinator	Projects (CAV & AV)	Physical infrastructure	Digital infrastructure	Data	Logical elements	Processing	Services
AUS State Government trials - ACT	Can drive trial	Sensors		CAV data			Trial
AUS State Government trials - QLD	Cooperative and Automated Vehicle Initiative (CAVI) Ipswich Connected Vehicle (ICV) Pilot Vulnerable Road User (VRU) pilot Connected and Highly Automated Driving Pilot (CHAD)	CITS station/Sensors	CITS	CITS/CAV data		CAV	CAV/NetOps services/Trial
AUS State trials - NSW	Regional automated shuttle trials	Sensors		CAV data		PT/CAV	CAV/PT services/Trial
	Sydney motorways automated vehicle trial	Sensors		CAV data		CAV	CAV/ NetOps services /Trial
	Cooperative intelligent transport initiative (CITI) trial	CITS station	CITS	CITS/CAV data		CAV	CAV/NetOps services/Trial
	CrashLab - Cudal test site in NSW	Testbed			Safety assurance	AV	Safety/mobility services
	NSW Automated Shuttle Bus Trial (Olympic Park)	Sensors		CAV data		PT/CAV	CAV/PT services/Trial
AUS State trials - NT	NT Electric Driverless Shuttle Bus Trial	Sensors		Sensor data		PT/Electric AV	PT services/Trial
AUS State trial - SA	Playford CAV Trial	Sensors		Sensor data		PT/Electric AV	PT services/Trial
AUS State trials - VIC	Omni-Aware Trial of Automated Vehicle Perception Equipped Intersection	Sensors		Sensor data		CAV	CAV services/Trial

Coordinator	Projects (CAV & AV)	Physical infrastructure	Digital infrastructure	Data	Logical elements	Processing	Services
	Monash-CityLink-Tullamarine automated vehicle trial, partnership of VicRoads, RACV and Transurban					AV	AV services/Trial
New Zealand	Bluetooth In-Car Messaging Trial in NZ	Testbed (V2I)	Bluetooth	Traffic Mng	Safety assurance	AV	AV/Safety services/Trial
iMOVE-University	Autonomous mobile lockers for city logistics (5-010)				Modelling	Freight/AV	Freight/AV services
	Vehicular network architecture using the 5G standard (5-017)	PC5 interface	5G (V2X communication)		Research	CAV	CAV services
iMOVE-Industry-University	Insurance research for AVs (1-004)				Standards/ Safety assurance	CAVs	Safety services
	Cohda Wireless trials driverless cars on Adelaide CBD (1-006)[1]	Testbeds (V2X communications)	sensors/GPS	CAV data		CAV	CAV services/Trial
	AV interaction with road infrastructure (1-007)	CITS station/Sensors/Clouds		Collecting CAV data	Trial	CAV	CAV services/Trial
	CHAD Safety Study (1-008)	CITS station/Sensors	CITS communication		Safety assurance	CAVs	CAV/ Safety services/Trial
	How safe are perception capabilities of AVs? (5-002)				Framework/ Safety assurance	CAVs	Safety services/Trial
	VRU and CAV interactions (5-006)				Modelling	CAV	NetOps services
	Optimising signal control in CAV and VRU mixed environments (5-009)				Modelling	CAV	NetOps services
	Flexible use case- autonomous shuttle trial (3-009)	Testbeds (V2I)	CITS communications	CAV data	Exchange	CAV/PT	CAV services/Trial
	HD maps for automated driving literature review (1-021)			HD map	Framework	AV	AV services

[1] The iMOVE Project 1-006 with Cohda and USyd focuses on the development of a general framework for cooperative data fusion to integrate data coming from different sources with their own uncertainties. These algorithms will be used to estimate and propagate estimates of position, context and associated risk for all road users and vehicles in proximity.

Coordinator	Projects (CAV & AV)	Physical infrastructure	Digital infrastructure	Data	Logical elements	Processing	Services
	CITS Pilot — Field Operational Test and Evaluation (1-002)	CITS station	CITS communications	CAV data		CAV	CAV services/Trial
	Security Credential Management System (1-005)	CITS station	CITS communications		Research	CAV	CAV services
	Accelerating uptake of CITS technologies (1-017)	CITS station	CITS communications	DSRC/5G	Research/modelling	CAV	CAV services
	Cyber security for connected vehicles and networks (5-003)	CITS station	CITS communications		Framework	CAV	Info/CAV services
	Promoting community readiness and uptake of CAVs (new)				Research/modelling	CAV	CAV services
	Vehicle to bicycle (V2B) safety interactions using 4G mobile devices (3-006)		4G	Sensor data		Micromobility/CAV	Safety/CAV services/Trial
	Improved network performance prediction through data-driven analytics and simulation (1-003)			AV data	Modelling	AV/mobility	AV/NetOps services
	Australia's public transport disability standards and automated vehicles (iMOVE EOI) (new)					PT/CAV	Public transport
University – Funded by Government and industry partnerships	Curtin University Trial- Navya bus		4G	AV data		PT/AV	PT/AV services/Trial
	University of Western Australia EasyMile Trial		Telstra 4G network	AV data		PT/AV	PT/AV services/Trial
	Lane Departure Warning Trial in rural roads of WA	Sensors		Sensor data	Safety assurance	AV	Safety services/Trial
	Flinders Driverless Bus Trial in SA					PT/AV	PT/AV services/Trial
TCA	National Telematics Framework	Sensors	4G	Telematics data	Framework	AV	AV/NetOps services
Defence CRC	Trusted Autonomous Systems	Testbed				AV	AV services
Industry – Funded by state	RACQ speed smart shuttle trials in Mt Cotton QLD	Testbeds (V2I)	CITS communications	CAV data			CAV services/Trial
	EasyMile and Transdev Driverless Shuttlebus Trial in SA					PT/AV	PT/AV services/Trial

Coordinator	Projects (CAV & AV)	Physical infrastructure	Digital infrastructure	Data	Logical elements	Processing	Services
government grants	SAGE Driverless shuttle and interactive transportable bus stop trial in SA	Transit station		CAV data		PT/AV	PT/AV services/Trial
	Lendlease Driverless Mobility Service Trial in retirement village in SA					AV	AV services/Trial
	Bosch CAV Highway Pilot Trial on Victorian Rural Roads and Highly Automated Driving Vehicle Partnership with VicRoads					AV	AV services
	Telstra and Lexus AV trial in VIC		4G cellular V2X communication			AV	AV services/Trial
	South Perth Bus trial in WA led by Royal Automobile Club (RAC)	Testbed				PT/AV	PT/AV services/Trial
	Autonomous Heavy Vehicle Platooning Trial in WA					Freight/CAV	Freight/CAV services/Trial
	RACT Driverless Electric Bus Trial in TAS					PT/Electric AV	PT services/Trial
Industry	RACT Driverless Shuttle Bus Trial in NZ	Sensors		Sensor data		PT/Electric AV	PT services/Trial
	Linfox-AARC automated truck testbed	Testbed		Sensor data		AV/Freight	AV/Freight services/Trial
ARRB-Industry-University	Driverless shuttle bus trial (La Trobe)					AV/PT	PT/AV services/Trial
ARRB-Industry	Eastlink L2 and CITS trial	CITS station			Modelling	CAV	NetOps services/Trial
	Yarra Trams CITS priority trial	CITS station	CITS communications			PT/AV	NetOps services/Trial
NTC	NTC Review of 'Guidelines for trials of automated vehicles in Australia'				Guideline for trials	AV	AV services
	NTC Discussion Paper - Regulating government access to C-ITS and automated vehicle data	CITS station	CITS communications		Regulations	CAV	CAV services
	NTC Policy Paper - Assuring the safety of automated vehicles				Guideline/ Safety assurance	AV	Safety/AV services
	Safety assurance system for automated vehicles in Australia				Guideline/ Safety assurance	AV	Safety/AV services

Coordinator	Projects (CAV & AV)	Physical infrastructure	Digital infrastructure	Data	Logical elements	Processing	Services
	NTC Consultation Regulation Impact Statement - Safety assurance for automated driving systems				Regulations/ Safety assurance	AV	Safety/AV services
	NTC Discussion Paper – Regulatory options to assure automated vehicle safety in Australia				Regulations/ Safety assurance	AV	Safety/AV services
	Changing driving laws to support automated vehicles- Policy Paper				Regulations	AV	AV services
	National enforcement guidelines for automated vehicles				Guideline	AV	AV services
	Government access to vehicle generated data			AV data	Guideline/Framework	AV	Info services
	In-service safety for automated vehicles				Guideline/Framework/ Safety assurance	AV	Safety/AV services
	Motor accident injury insurance and automated vehicles				Guideline/Framework/ Safety assurance	AV	Safety/AV services
Austroads	Guidance and Readability Criteria for Traffic Sign Recognition Systems Reading Electronic Signs (AP-R627-20)				Guideline	Mobility/AV	NetOps/AV services
	Future Vehicles 2030 (AP-R623-20)				Modelling	CAV	CAV services
	Education and Training for Drivers of Assisted and Automated Vehicles (AP-R616-20)				Research	AV	AV services
	Infrastructure Changes to Support Automated Vehicles on Rural and Metropolitan Highways and Freeways: Emerging Asset Information Technology (Module 4) (AP-R605-19)	Infrastructure			Research	AV	AV services
	Infrastructure Changes to Support Automated Vehicles on Rural and Metropolitan Highways and Freeways: Audit Specification (Module 1) (AP-T347-19)	Infrastructure			Research	AV	AV services
	Infrastructure Changes to Support Automated Vehicles on Rural and Metropolitan Highways and Freeways: Asset Standards (Module 3) (AP-R604-19)	Infrastructure			Standards	AV	AV services

Coordinator	Projects (CAV & AV)	Physical infrastructure	Digital infrastructure	Data	Logical elements	Processing	Services
	Infrastructure Changes to Support Automated Vehicles on Rural and Metropolitan Highways and Freeways: Road Audit (Module 2) (AP-T348-19)	Infrastructure			Research/field audit	AV	AV services
	Infrastructure Changes to Support Automated Vehicles on Rural and Metropolitan Highways and Freeways: Project Findings and Recommendations (Module 5) (AP-R606-19)	Infrastructure			Research/Framework	AV	AV services
	C-ITS Compliance Assessment Framework for Australia and New Zealand (AP-R585-18)	CITS station	CITS		Framework	AV	AV services
	Evaluation of the European C-ITS Platform including Threat, Vulnerability and Risk Analysis (AP-R584-18)	CITS station	CITS		Standards	CAV	CAV services
	Operations of Automated Heavy Vehicles in Remote and Regional Areas (AP-R579-18)				Research/Framework	AV/Freight	AV/Freight services
	Connected and Automated Vehicles (CAV) Open Data Recommendations (AP-R581-18)			CAV data	Research/Framework	CAV	Info/CAV services
	Safety Benefits of Cooperative ITS and Automated Driving in Australia and New Zealand (AP-R551-17)				Research/ Safety assurance		Safety/CAV services
	Guidelines for Trials of Automated Vehicles in Australia (AP-C101-17)				Guideline for trials	AV	AV services
	Assessment of Key Road Operator Actions to Support Automated Vehicles (AP-R543-17)				Research	AV	AV services
	Registration, Licensing and CTP Insurance Issues Associated with Automated Vehicles (AP-R540-17)				Research/ Safety assurance	AV	AV services
	Privacy Impact Assessment (PIA) for Cooperative Intelligent Transport System (C-ITS) data messages (AP-C100-17)	CITS station	CITS	CAV data	Research	CAV	CAV/Info services
	Concept of Operations for C-ITS Core Functions (AP-R479-15)	CITS station	CITS		Research	CAV	CAV services
	Cooperative Intelligent transport systems (C-ITS) Standards Assessment (AP-R474-15)	CITS station	CITS		Standards	CAV	CAV services

Coordinator	Projects (CAV & AV)	Physical infrastructure	Digital infrastructure	Data	Logical elements	Processing	Services
	C-ITS Interoperability with Existing ITS Infrastructure (AP-R458-14)	CITS station	CITS	CAV data	Framework	CAV	CAV services
	Emerging Digital Mapping Requirements for C-ITS (AP-R432-13)	CITS station	CITS	CAV data	Framework	CAV	CAV services
DITRDC	CITS Deployment (new project)	CITS station	CITS		Research	CAV	CAV services
City of Melbourne	5G and IoT testbed in Melbourne	Testbed	5G	IoT data		Mobility	Mobility services
Standards Australia	Standards Australia IT-023				Standards		
ISO	ISO TC 204/ CEN TC 278				Standards		
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Monash Uni	Monash Connected Autonomous Vehicle (MCAV) student team					CAV	

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Table 3 - MaaS

Coordinator	Projects (MaaS)	Physical infrastructure	Digital infrastructure	Data	Logical elements	Processing	Services
iMOVE-Industry-University	MaaS and On-Demand Transport – Consumer Research and Report, National (3-001)				Modelling		
	Parking management in the smart mobility age (3-002) in QLD			Parking data	Modelling	Mobility	Info services
	MaaS trial in Sydney, NSW (3-003)						Trial
	Free-flow parking for car-sharing in VIC (3-004)				Modelling/Framework	MaaS	Car-sharing services
	Data use for improved transport management and journey reliability (1-001)- in conjunction with AIMES			Multimodal data	Research/Modelling	Mobility	Info services
	MaaS business models: Lessons for operators and regulators (3-005)				Modelling/Framework	MaaS	
University –Funded by Government and Industry Partnerships	Australian Integrated Multimodal Ecosystem (AIMES) Test Bed in VIC	Testbed	Sensors	Sensor data	Data collection	Mobility	Multimodal NetOps/MaaS services/ Trial
Austroads	Opportunities in MaaS (AP-R601-19)				Research	MaaS	MaaS services
State Government - NSW	MaaS Data Specification			Multimodal data (e.g. GTFS, GTFS Realtime, and GBFS)	Standards	MaaS	MaaS services
	NSW MaaS Innovation Challenge (Uber, Lynxx (Tranzer app), MaaS Global (Whim app), Swiftfare Fleet, Skedgo, Tripgo)-TfNSW Transport Digital Accelerator					MaaS	MaaS services/ Trial
	NSW Waverly Transport Innovation Challenge			Multimodal data		MaaS	MaaS services/ Trial
Industry – support from state government	Via's trial in Newcastle and Sydney					MaaS	MaaS services/ Trial
State Government - QLD	QLD Logan Demand Responsive Transport (DRT) Trial					MaaS	MaaS services/ Trial

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QLD Logan Demand Responsive Transport (DRT) Trial, http://www.movingpeople.com.au/LiteratureRetrieve.aspx?ID=244895

Via’s trial in Newcastle and Sydney, https://www.austrade.gov.au/future-transport/case-studies/via/

Table 4 – Others

Coordinator	Projects	Physical infrastructure	Digital infrastructure	Data	Logical elements	Processing	Services
iMOVE-Industry-University	Enhanced vehicle detection at traffic signals and on smart freeways (1-018)	Sensors	Vehicle detection System (VDS)	Sensor data	Research/Modelling	Mobility	NetOps services/Trial
	Green wave for high capacity public transport services (5-001)	Sensors and Signals		Sensor data	Research/Modelling	PT	NetOps services / PT services
iMOVE-industry	Multi modal operation of smart intersections (5-011)	Sensors and Signals	Camera, loops, LIDAR, DSRC, Wifi, Bluetooth	Sensor data	Research/Modelling	NetOps services	
Councils	SCATS	Sensors and signals	Induction loops	Sensor data	Application	Mobility	NetOps services
Councils	STREAMS	Sensors and signals	Induction loops	Sensor data	Application	Mobility	NetOps services
Councils	Smart Motorways	Sensors and signals	Induction loops	Sensor data	Application	Mobility	NetOps services
Councils	ICMP (NSW)	Sensors and signals	Induction loops	Sensor data	Application	Mobility	NetOps services
Councils	Traffic Management Centres	Sensors and signals	Induction loops	Sensor data	Application	Mobility	NetOps services
Councils	Incident Management Systems	Sensors and signals	Induction loops	Sensor data	Application	Mobility	NetOps services
Councils	Variable Messaging Systems	Sensors and signals	Induction loops	Sensor data	Application	Mobility	NetOps services
Cohda	Locate IQ (Cohda)		5.9 GHz	**Sensor data**	Applications	Mobility	CAV, NetOps
TAC	TAC trial of bicycle light technology	Sensors	Wifi, Bluetooth	**Sensor data**	Application	Mobility	Safety services
iMOVE-Industry-University	Future of travel demand modelling and forecasting (1-010)				Review/Modelling	Mobility	NetOps services
	Integrated land use and transport modelling (1-011)			Landuse and macroscopic demand data	Research/Modelling	Mobility	NetOps services

Coordinator	Projects	Physical infrastructure	Digital infrastructure	Data	Logical elements	Processing	Services
	Econometrics, land use and strategic transport models (1-023)			Landuse and economic data	Research/Modelling	Mobility	NetOps services
	Working from home: Revising metro strategic transport models (1-031)			SP survey data	Research/Modelling	Mobility	NetOps services
iMOVE-University	Demand management /estimation in large-scale traffic networks (5-020)			Traffic management data	Research/Modelling	Mobility	NetOps services
	Macroscopic Fundamental Diagram measuring flow and density (5-022)			Sensor and probe vehicle data	Research/Modelling	Mobility	NetOps services

Coordinator	Projects (Public Transport)	Physical infrastructure	Digital infrastructure	Data	Logical elements	Processing	Services
iMOVE-Industry-University	Measuring demand for bus replacement services (1-009)				Research/Modelling	PT	PT services
Coordinator	**Projects (Transport system)**	**Physical infrastructure**	**Digital infrastructure**	**Data**	**Logical elements**	**Processing**	**Services**
iMOVE-Industry-University	Managing transport system investment risk (3-007)				Framework	all	all
	Exploring the movement and place framework (1-014)		Virtual Reality	Ped tracking data	Research	Micromobility	Safety services
iMOVE-ARRB	Conceptual architecture for future transport and mobility environment (3-008)				Framework	all	all
Coordinator	**Projects (ITS)**	**Physical infrastructure**	**Digital infrastructure**	**Data**	**Logical elements**	**Processing**	**Services**
Austroads	National ITS Architecture Framework (NIAF)				Framework	Mobility	
	National ITS Product Type Approval Process (NIPTAP)				Protocol	Mobility	
	NEVDIS National Exchange of Vehicle and Driver Information Services				Protocol	Mobility	
	Australian Safety Barrier Assessment/ Installation Accreditation Scheme				Protocol	Mobility	
ITS Australia	Michigan Australia Exchange				Protocol	Mobility	
	National Transport Data Community of Practice (NTD-CoP)				Protocol	Mobility	
	Australian Traffic and Traveller Information Forum (ATTIF)				Protocol	Mobility	

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Table 5: Other elements

<table>
<tr>
<td><u>Connectivity</u>
• Secure 4G/5G connectivity
• Cloud hosted CITS message management services
• Secure data hub platform
• Data exchange
• Augmented location service
• Big data storage and analysis</td>
<td><u>ZEV infrastructure</u>
• Public network
• Private network (Chargefox, Tesla, Toyota, etc)
• Fast and Ultra Rapid Chargers</td>
<td><u>BIG Data</u>
• Government data
• Tolling (NETC) data
• TCA IAP TIX
• Crowd sourced data (HERE, Google, TomTom, Telstra, Optus)
• In-vehicle data (SUNA)
• OEM data
• Industry data
• National Data Hub, Data Exchange (DITRDC)</td>
<td><u>Architecture</u>
• NIAF
• HARTS (for C-ITS)
• Integrated Mobility Service Concept
• Roles and Responsibilities for ITS Service Applications
• (see report)</td>
</tr>
<tr>
<td colspan="4"><u>Strategic Plans</u>
• National Land Transport Technology Action Plan 2020-2023, Transport and Infrastructure Council (Canberra)
• Our Strategic Plan 2019-23, Department of Transport (Victoria)
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