Managing Transport System Investment Risk

Enhancing patronage predictions and adapting strategic asset management and appraisal processes to account for emerging trends and uncertainty: Close-out Report

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About PATREC

The Planning and Transport Research Centre (PATREC) is a collaboration between the Government of Western Australia and local universities, constituted to conduct collaborative, applied research and teaching in support of policy in the connected spaces of transport and land use planning. The collaborating parties are: The University of Western Australia, Curtin University, Edith Cowan University, Department of Transport, Main Roads Western Australia, Western Australian Planning Commission and the Western Australian Local Government Association.

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1. Introduction

1.1. Overall policy need

The context for transport planning activities is changing, as technology development, consumer demand and transport service business models change, and it is expected that there will be further changes on the horizon due to connected, shared, electric and automated vehicles, as well as other new and future changes in travel behaviour. Long term transport infrastructure, planning and policy decisions are increasingly made in an environment that is volatile, uncertain, complex and ambiguous.

At the same time, the quantity and quality of public and privately-owned transport data is increasing and there are emerging opportunities to improve our planning tools. Changes in technology also open avenues to improve transport service options (e.g. mobility as a service) and better optimise the use of the transport system. The assumptions that underlie existing public transport prediction models have not yet been adjusted to account for recent and emerging trends in the transport environment

Given the changing context for transport planning, the Transport Portfolio needs to consider what improvements can be made to existing practice and processes to ensure decision makers have the best possible advice, considering potential changes in the transport system.

Adapting portfolio-wide strategic infrastructure investment planning and management tools, guidelines and frameworks is required to account for recent trends and emerging risks, in particular:

- patronage forecasting tools through an advanced understanding of factors influencing patronage trends;
- digital journey planning tools;
- asset management guidelines; and
- project assessment and prioritisation frameworks.

1.2. Specific policy needs

1.2.1. Factors influencing patronage trends

Public transport patronage forecasting models currently used have previously been adequate in predicting public transport patronage with reasonable levels of accuracy. These models were however unable to predict the decline in fare-paying boardings, evident since 2012/13 (although there are signs of some improvement in patronage from 2019). This has significant implications for prediction of fare revenues, provision of operating subsidies and the ability to anticipate changes in public transport demand to inform levels of service provision and future investment decision making. Contributing factors proposed to date include CBD office vacancy rates, fuel prices, public transport fares and the uptake of ride sharing. The significance of these relationships has not been statistically confirmed and there is a need to undertake more robust and detailed analyses

A range of socio demographic trends which are likely to have a bearing on public transport use are also emerging (e.g. lower licence acquisition and car ownership amongst millennials, greater casualisation of the workforce, increased working from home etc.). Research and analysis to explore the relationship between public transport usage and these broader trends is warranted to inform transport and economic models as well as policy and project development. In particular, the research is required to inform the work of the Transport Portfolio's Public Transport Optimisation (PTO) project. Another driver for this research is to facilitate the development of a range of customer-centric initiatives to optimise (public transport related) travel behaviour in the short term as a precursor to development work on longer term service innovation initiatives.

1.2.2. Digital journey planning impact on travel choice

Individual transport customers rely on various digital information sources to plan and maintain routine travel. At present these sources include private journey planners such as Google Maps and State Government services such as the Transperth Journey Planner. Despite the popularity of these services, their use and associated impact on mode share is not well understood within the Perth context. Do these services facilitate mode change, or have they contributed to the changes in mode share observed between the 2011 and 2016 Censuses? How can these services be improved or supplemented to optimise use of the transport network?

As Perth continues to see changing trends in the usage of differing transport modes – with both the introduction of Mobility as a Service (MaaS) options and a decrease in public transport patronage – the impact of digital journey planners continues to remain unexplored. These journey planners, software applications which run on a variety of systems including now-ubiquitous smartphones, allow transport consumers to better understand and interact with the operational characteristics of differing transport modes. The research will inform planning and decision-making processes throughout the Transport Portfolio, particularly digital journey planning services, MaaS, travel behaviour change, public transport optimisation with associated business case development and project prioritisation.

1.2.3. Asset management

Road asset planners and managers are guided in their work by international, national and state standards and guidelines such as ISO 550000 series and PAS 55 on asset management, ISO 31000 on risk management, Austroads GAM and Austroads Road Design Guidelines, WA Treasury Asset Management Guidelines, to name the most relevant. Disruptive technologies such as CAV may result in changes to the established practice of asset planning and management resulting in the need to revise and adapt relevant guidelines. The findings of this research will offer a strategic perspective on how to rethink the way transport infrastructure assets facilitate the delivery of services into the future; and how to plan for and manage transport infrastructure assets in the future.

1.2.4. Infrastructure project appraisal

Decision making about infrastructure investment is based on the net impacts measured by the host government through project evaluation. Project evaluation is a process of measuring impacts and risks of a project for the purpose of assessing and prioritising projects, in order to ensure that the project is beneficial with respect to the public good. The Transport Portfolio needs to consider future uncertainties within their project assessment and prioritisation framework to ensure that their advice to the decision makers considers potential future changes to the transport systems. The research will also complement other initiatives within the Transport Portfolio including the update of the Investment Decision Framework.

1.3. Project aims and objectives

The project aim was to enhance and adapt selected portfolio-wide, strategic transport infrastructure investment planning and management tools, guidelines and frameworks, to account for emerging risks and trends in order to ensure that decision makers have the best possible advice on which to base infrastructure investment decisions, considering the uncertainty of potential changes impacting the transport system.

The project objectives were to:

1. determine the **systemic factors driving patronage shifts** (including long term labour market characteristics, post GFC demographic shifts, increased capacity in road

infrastructure, CBD parking costs and transport trends such as: ridesharing, licenses, fuel prices, vehicle ownership), to: (i) enhance the public transport patronage forecasting model for the improved prediction of fare revenues, operating subsidy requirements, levels of service provision and service innovations; and (ii) to facilitate the development of a range of customer centric initiatives to optimise (public transport related) travel behavior;

2. understand customer experiences of **digital journey planning** services and influence on mode share for all routine trip purposes (work, school, shopping, recreation, etc) and identify potential improvements to journey planning services in order to ultimately inform the development of a range of customer centric initiatives to optimise (non-car based) travel behavior;
3. identify specific impacts of specifically, CAV, disruptive technologies on road (and road/rail interface) asset management practice as well as response actions and opportunities for innovation in order to adapt templates and guidelines; and
4. propose adaptation strategies to appraise the uncertainties of emerging technologies within the project assessment and prioritisation framework to ensure that advice to decision makers explicitly considers potential future changes to the transport systems.

1.4. Purpose of this report

The research was conducted through four separate sub-projects corresponding with the four research objectives. Each sub-project has a final report, including Executive Summary, detailing the specific objectives, methodology and results. The intention with this close-out report is to provide a consolidated summary of findings across the four sub-projects as well report on the dissemination of the research, policy impacts and recommendations for further research.

2. Research approach

2.1.1. Understanding systemic factors driving patronage shifts

Bus and train patronage data were investigated using spatial regression, latent growth and difference-in-difference analysis; and pattern recognition clustering techniques, to understand and estimate public transport demand relationships in relation to:

- factors influencing public transport patronage trends over the period **2009 to 2019 (Phase 1)**
    - Internal – fares, price of competing modes (e.g., car ownership and use, fuel price, quality of service (service kilometres), journey distance (O-D)); and
    - External - economic activity indicators (unemployment, state national product, wage index, transport price index, office vacancy rates, number of visa workers, CPI, mining jobs), and city-wide accessibility (travel time between origins and destinations).
- a more detailed assessment of factors associated with changes in public transport ridership in terms of spatial variation and variation across different user profiles between **January 2015 and August 2019 (Phase 2)**
    - Internal (to transport system) factors – fares, extent of service (service kilometres), provision of park-and-ride bays, road congestion, and journey distance (origin-destination O-D); and
    - External – socio-economic activity indicators (population density, unemployment, vacancy rates), city-wide accessibility (travel time between O and D), as well as urban facilities present within suburbs.

2.1.2. Determining digital journey planning impacts on patronage

An understanding of the use of journey planning apps and associated impact on mode share within the Perth context was obtained through:

- building a comprehensive understanding of customer use and experiences of digital journey planning services for all routine trip purposes (work, school, shopping, recreation, etc),
- determining the influence of journey planning on mode share;
- identifying gaps in journey planning information and their influence on mode choice; and
- making recommendations relevant to journey planning services within the context of MaaS.

Firstly, a literature review was undertaken to ascertain survey techniques for travel behaviour and mobile app usage. This led to the use of a stated preference-style survey where respondents described what they had done with respect to transport and journey planner usage and what their preferences were in the future.

Next, a market analysis of journey planning applications was undertaken of approximately 40 apps and websites to understand what features they provided and which apps provided which features.

A computer assisted telephone interview survey was then undertaken of 402 Perth residents over the age of 18, which was considered representative when considering the parameters of the sample, which were considered 'standard' for a survey of this scope. Due to the COVID-19 pandemic, the scope of the survey was extended to also understand how travel behaviour had changed due to the pandemic.

2.1.3. Adapting strategic road asset management practice to account for uncertainty relating to CAVs

Guidance on strategic asset management planning for transport infrastructure and service delivery in the future to account for uncertainty of CAVs was provided through:

- offering a strategic perspective to rethink the way transport assets facilitate the delivery of services into the future; and
- establishing a guideline for setting business development objectives and contributing to desired strategic asset management outcomes in the next generation transport context.

This sub-project explores how they may affect the asset and the business of managing the asset, throughout its life cycle. More specifically, the impact of CAV on asset management is assessed according to:

- two CAV uptake scenarios: less than 100% uptake and 100% uptake; and
- six key asset management areas: policy, strategy, planning, legislation and statutory requirements, customer and stakeholder expectations and risk management.

2.1.4. Adapting infrastructure project prioritisation to account for uncertainty relating to disruptive technology

Strategies to assess the uncertainties of emerging technologies within the assessment and prioritisation framework were determined through an investigation of:

- potential impacts and implications of emerging technologies on transport infrastructure, planning and policy;
- how the uncertainties of emerging technologies can be assessed within infrastructure investment assessment and prioritisation; and
- how the assessment of uncertainties can be incorporated into the revised infrastructure investment assessment and prioritisation framework.

This study explores literature to first determine a Transport Infrastructure Investment Assessment (TIIA) framework that is used typically in practice, and second to identify the impacts and uncertainties of future mobility and transport (FMT). It then proposes a methodology that can

improve the TIIA framework. The proposed methodology is then applied to a real-life context using recent major transport projects. Through this, its limitations are identified and the conclusion is developed.

The literature review aims to provide sufficient knowledge of TIIA frameworks, particularly those that are used in practice, and the impacts and uncertainties of FMT. The scope of the review includes the literature that describes the TIIA frameworks that are used in Australian practice and the impacts and uncertainties of FMT. The implications for infrastructure investment assessment and prioritisation processes are explored by examining how the potential impacts can change the assessment outcomes.

Through reviewing existing TIIA frameworks, this study will explore appropriate ways to improve the framework to account for the uncertainties of FMT. The proposed additional tasks should not disrupt the existing process and/or require substantial additional resources. Therefore, this study needs to identify the TIIA tools currently used, the data required in the assessment and the tasks involved in the activities. Also, the appropriateness will be determined, while considering the impacts and uncertainties of FMT to ensure that the proposed methodology effectively assess them.

Once the proposed methodology is defined, it is applied in a real-life context by assessing existing transport investment proposals to test its applicability and practicality. This process can improve the methodology and identifies its limitations. Three recent major transport investment proposals from Australia are used. These are Brisbane Metro (QLD), METRONET: Yanchep Rail Extension (WA) and North East Link (VIC), which are all identified as high priority by Infrastructure Australia (Infrastructure Australia, 2020).

3. Summary of findings

3.1. Factors influencing public transport patronage trends

Perth patronage trends during the period 2009-2019 follow an S-shape curve with three periods of change: growth, decline, and recovery, consistent with the variation of the economic indicators.

For the metropolitan areas as a whole:

- For **all journeys** across the metropolitan area (for commuting and other purposes, all ticket types, all times) fare is a significant contributing factor to patronage numbers, second in importance only to bus service coverage and frequency.
- For **all journeys** across all areas, bus service frequency and coverage (measured by bus service kilometres) is the most important factor, followed by fare and then economic factors (worker migration rates (worker visas) and employment rates).
- For **commuting journeys**, the most important contributing factors are, as with the case of all journeys, bus service frequency and coverage (measured by bus service kilometres), followed by fare, then economic conditions (CBD office vacancy rates plays an important role here because it is a strong indicator for the number of jobs in the city).
- Demand elasticities with respect to fares are -0.62 for all fares and -0.78 for commuting.

Spatial variation:

- Fare is relatively more important for **commuting journeys** from outer areas – that is fare is relatively more important on longer commutes.
- For **commuting journeys**, second to bus service frequency and coverage, fares are most important in outer areas while in inner areas, economic conditions (CBD office vacancy, employment rates) are more important than fares.
- Bus service frequency and coverage matters most. For **all fares**, service km (which include local trips) the fares to bus service ratio is smallest for outer suburbs. However, when considering **commuting journeys** to the CBD and inner suburbs, the fare to bus service km is lowest for these outer suburbs.

- For **commuting journeys** from outer areas, fare is twice as important as CBD office vacancy rates for outer areas.
- For **commuting journeys** from inner areas, fare is approximately half as important as office vacancy rates.
- Commuting elasticities are higher for 'Outer' zones.
- Whilst there are statistically significant differences across the three zones it is difficult to argue that the magnitudes are sufficiently different to affect policy.

The more refined analysis (for different spatial areas, fare type, and factors) for the more recent period (2014 – 2019) has shown that:

- Congestion on the roads is a significant factor some fare types indicating that continuous improvement of road conditions (additional lanes, widening, traffic signalling etc.) can increase driving and decrease public transport patronage.
- Park & Ride (PnR) bays at stations play an important part of Perth's public transport network, i.e., the count of bays is a significant explanatory variable for where standard fare travellers commence their journeys.
- Level of service as measured by bus service km is significant for all fare types.
- Destinations with good public transport accessibility – as measured by the average journey time to reach the destination – are associated with higher demand.

Applying the advanced regression analysis results, a number of forecasting scenarios were used to explore the effects of changing selected internal factors (fare, bus service kilometres) on patronage. The various scenarios produced a range of patronage effects from a decline in number of journeys of -1.5% to an increase of 1.7%.

3.2. Digital journey planning impacts on patronage

The research showed that approximately two-thirds of respondents used journey planners at least 'occasionally', indicating that these systems are an important service and hence their ability to function consistently and accurately impacts the travel decisions made by respondents.

A wide range of journey planners were found to be used on a variety of devices, with Google Maps and the Transperth apps most common, with many users also using Apple Maps and Uber. Primarily, this was on smartphones such as the Apple iPhone.

Many consider journey planners only relevant to shared and active transport modes. It was found that the vast majority of respondents (approximately 88%) used them for car trips taken as a driver. Approximately one-fifth of respondents who used journey planners used them for journeys including a bus and one-quarter of respondents used journey planners for journeys including a train.

Approximately 90% of respondents that used journey planners used them for new journeys they had not undertaken before, approximately three-fifths of these respondents did not use journey planners for regular journeys undertaken. Interestingly, a third of respondents indicated that they had used journey planners within multi-modal journeys.

While travel time estimation and routing/navigation were deemed useful by most respondents, there was also a level of importance given to live journey information such as live travel time. There was, however, an unmet need of information regarding the destination within journey planners such as search and discovery of the destination – such as attractions at the destination or 'services' such as food or petrol along the way.

New information such as weather information, environmental impact, booking and paying in advance alongside alternate formats (such as smart speakers) were also of interest to

respondents. Many suggestions were provided for rewards systems, however the most popular suggestions either involved money or equivalents or were related to discounts on travel.

Most respondents indicated that their behaviour would not be changed by these improvements. However, approximately one-fifth of respondents indicated that there was at least a moderate likelihood that these changes would lead to behaviour change.

The COVID-19 related questions showed that:

- Travel demand markedly decreased during the pandemic, with over two-thirds of respondents indicating that they had reduced the number of journeys taken with only 3.7% of respondents indicating that they had increased their journeys. This was to be expected with restrictions introduced and reductions in activities due to the pandemic.
- The number of respondents working from home approximately doubled compared to before the pandemic, with a drop of approximately two-thirds in the number of respondents who used public transport to get to work during the pandemic, compared to before. Similar changes were seen for journeys undertaken for social/recreational purposes.
- Most responses indicated the return of activities in some manner would be an impetus to increase journeys undertaken again, however there was a reasonable number of respondents (approximately 8%) who indicated that the fear of catching the virus would prevent them from using shared modes and hence it is implied they would wait for the virus to disappear before using these modes.

Recommendations to ensure the continued use and availability of journey planners:

- Ensure the continued supply of accurate and timely transport data in an open format - there is a desire for live and timely transport data from respondents, and the survey has shown that respondents use many different apps to access this data. As such, making 'live' information about the transport network – road, active and public transport – available to third-party apps will ensure that it is spread as widely as possible to end users of the system.
- Ensure the continued supply of accurate 'secondary' data in an open format - the provision of information regarding the accessibility of infrastructure in a standardised format will also ensure maximum usability of shared transport modes by those with accessibility difficulties eg. number of park and ride bays at railway stations, condition and slope of cycle and walking paths.
- Continue development of the Transperth app - the Transperth app remains a popular choice of transport users within Perth. As such, its use should be continued to be encouraged and supported as to not alienate existing users. Integration of weather information within journey planners was identified as a popular feature by respondents and could be implemented within the Transperth app, providing not only an enticement to public transport users but a novel innovation compared with most other journey planners. Such changes will not only improve the attractiveness and usage of the Transperth app through increased functionality but can also provide a base for mobility-as-a-service systems in the future.
- Investigate travel discounts for continued use of public and active transport modes - there is a desire from respondents to be rewarded for continued 'good' use of transport systems. While monetary incentives are a common reward identified by respondents, providing travel discounts is a popular response that encourages further use of said desirable modes.
- Investigate provision of data in new and novel formats - many respondents identified the provision of transport data in alternate formats as a desirable feature within journey planners. While this could take many forms, one popular format that has been used by other transport operators – notably airlines including Virgin Australia and Qantas – is integration with 'smart speaker' assistant systems such as Amazon Alexa to provide information regarding transport services.

- Provision of pre-booking of public transport including integration with Apple Pay and Google Pay - also identified by respondents was a desire to integrate transport use with digital wallets such as Google Pay and Apple Pay. This can be taken further to allow for the purchasing of tickets through a smartphone, providing further convenience for transport users. Pre-booking a service, while separate to this, can be integrated with such digital wallets to reduce the friction of public transport usage and also to provide one component of a mobility-as-a-service system.

3.3. Adapting strategic road asset management practice to account for uncertainty relating to CAVs

The findings of the project are that CAV uptake will:

- Affect asset management in many areas including policy, strategy planning, customer and stakeholder expectation, statute and legislation and risk management.
- Provide several opportunities for improving asset management outcomes including improved road safety, decreased carbon emission, reduced traffic congestion, improve mobility, intermodal integration, optimised supply chains and reduced transport cost.
- Present also some challenges, particularly in relation to managing a rapidly changing transport market with a transition to Mobility as a Service (MaaS) and the rapid increase in micro-mobility, fueled by technology changes and increased customer expectations re: improved mobility.

In terms of the big picture for CAV uptake, asset managers need to be proactively engaged with three key areas:

- Development of a framework for digital infrastructure to support safe, cybercrime protected vehicle-to-vehicle and vehicle-infrastructure communication:
    - Apart from sensors that capture data about an AV's physical environment, the use of data from other sources external to the vehicle must be included to support a comprehensive understanding of the data.
    - The provisions for collecting, sharing, storing and owning data require interventions from the government to introduce protocols to control the data related to CAV.
    - The introduction of legislation and associated regulations should align with the global technology to ensure Australia as a key player in the global market for CAV.
    - Data could provide key insights for manufacturers and consumers. This approach could include the availability of data in real-time and post real-time for specific platforms such as CAV and AVs. This approach will help the asset managers to better plan infrastructure for <100% and 100% uptake of CAV.
    - The current advancement of CAV is technology agnostic. Rather than asset managers adapting the road infrastructure to the dynamic technological needs to accommodate CAV, the CAV had to adapt to the current road infrastructure to make progress as a future mobility solution
- National policies, standards, governance and regulation for CAV uptake and CAV infrastructure decisions:
    - It is essential that Australia does not miss out on the benefits of CAVs.
    - The Commonwealth and state governments should establish competitive grants programs that encourage the trial of CAV technologies that can be adapted to the geographical or climatic conditions that are unique to Australia. This will further ensure that a standard is maintained unique to Australia.
    - State, territory and local governments should plan for and adapt to future changes to Australia's AV fleet by undertaking consistent policies across all jurisdictions
- Provide mechanisms to improve safety
    - Eliminating humans from driving would result in less or nil concentration lapses, road rage incidents, misjudgements, sensory limitations, drink and drug-affected

driving and other causes of crashes. Further, there are issues related to safety incidents caused by the technology – e.g. Tesla fatalities caused by automated driving systems. These situations provide a case for policies designed to encourage 100% uptake of CAV. Sufficient evidence on a safe, efficient and equitable transport system by the introduction of CAVs will help government commit to spending funds on CAV infrastructure.
    - Computer hacking and terrorism by malicious hackers of both CAV and smart infrastructure are serious concerns.
    - The existence of other policy options such as pricing could ensure people are discouraged from using non-AVs or non-shared private travel.

Overall, it is difficult to predict with a high degree of confidence all the implications for asset management resulting from the uptake of CAV especially at the 100% uptake point. Asset managers need to constantly monitor CAV technology progression, capture results of trials and any relevant information available, be involved and contribute to national policies and be ready to adapt their practice as required.

3.4. Prioritisation of infrastructure investment proposals in the face of uncertainty

The study recommended scenario testing using a MCA approach, incorporated within the existing Infrastructure Australia framework (Infrastructure Australia, 2018a), as the most suitable tool for assessing the uncertainties of FMT due to technical, practicality and applicability advantages.

Testing the applicability and practicality of the recommended framework in relation to a) existing strategic transport scenarios (Transport Portfolio, WA) and b) three large infrastructure projects found:

- Overall, the following assumptions typically used in scenario assessment, are found as the key factors that can influence the assessment outcomes:
    - Changes in demand for PT;
    - Electric vehicle and AV uptake;
    - Assumption relating to congestion and pollution;
    - Strategic objectives/directions; and
    - Assumptions relating to economic growth.

- Assessment outcome is considerably influenced by certain features of the project scope:
    - The nature of the work, whether the project is a road, PT or active travel project;
    - Integration of technology features, such as better journey planning tools and more efficient operation management systems;
    - Being integrated within wider transport optimisation and service integrations, such as being part of the MaaS scheme; and
    - The testing revealed that the uncertainties associated with social value were not fully captured. This can be due to the lack of comprehensiveness of the scenarios, leading to a shortage of assumptions relating to social value in the scenarios used in this study. This limits the assessment's ability to assess the uncertainties associated with social value. Similarly, across all scenarios, the changes in deliverability criterion also suffered from lacking related assumptions. Additionally, the assessment suffers from a key limitation of MCA, which is the risk of subjectivity.

Through the testing, first, considerable demand uncertainties were evident, which can lead to uncertainty in all benefits and disbenefits. This emphasises that all resulting impacts due to changes in demand need to be exclusively assessed under the "changes in utilisation" criterion. It

also suggests that the disruption of FMT needs to be fully understood when undertaking the assessment. Second, it found that the projects that are often inflexible in the way they can be used, are exposed to more uncertainties than others. Third, the comprehensiveness of the assessment depends on the comprehensiveness of the scenarios. Fourth, identifying "triggers' would be useful as it can flag potential loss of utilisations without any detailed analyses, which can be identified through the assessment of FMT uncertainty.

This study considered both an increase and decrease of utilisation. This is particularly important, given that the increase can offset the decrease, because overall network-wide impacts need to be considered in infrastructure planning, even when assessing at project-level.

4. Dissemination

4.1. Academic publications

A number of publications have been planned and commenced. Academic publication based on the research conducted in this project will proceed long after the closure of this project. In accordance with the PATREC and iMOVE CRC agreements, drafts will be shared with industry partners and iMOVE prior to publication.

Journal paper – working title	Journal/s to be targeted	Sub-project
Forecasting patronage using spatial-temporal series	Transportation Research A	Patronage trends
A spatial model for patronage demand	Transportation	
Passenger churn and long-term behaviour of public transport usage using micro-data	To be decided	
Analysis of views and behaviours of Journey Planners in Perth, Australia	Case Studies in Transport Policy	Digital journey planning
Incorporating the Future Mobility and Transport Uncertainty Assessment into Current Transport Infrastructure Investment Assessment Frameworks	Transportation Research: Part A: Policy and Practice or Transport Policy	Factors influencing public transport patronage trends
Uncertainties of Autonomous Vehicles as disruptive technology in transport infrastructure planning and policy" paper	Asia Pacific Journal of Marketing and Logistics	Asset management
Adapting Strategic Asset Management Practice for Autonomous Vehicles	Transport Reviews	
Redefining Strategic Asset Management for Connected and Autonomous Vehicles using Policy Delphi Techniques	Public Management Review	
Do Effective Policies and Practices in Connected and Autonomous Vehicles support Effective Safety Outcomes	Reliability Engineering & System Safety	

The “Now, Near and Next” of Autonomous Vehicles (AVs): A Document Analysis on current practices on AVs	Construction Management and Economics	
Conference paper	Australian and New Zealand Academy of Management (ANZAM) Annual Conference, Perth, December 2021.	

4.2. Industry stakeholder presentations

Sub-project focussed dissemination took place in the form of presentations to and discussions with small targeted stakeholders. A PATREC seminar planned to be held in the first half of 2021, will showcase all sub-projects at a high level, to a wider audience. In addition, In addition, as the opportunity arises, sub-project outcomes will be disseminated more widely eg. iMOVE forums and government forums eg. further presentation to PTOPS committee and National webinar via Engineers Australia and Asset Institute (early 2021).

Sub-project	Form and Date	Participation
Factors influencing public transport patronage trends	Presentation to the Public Transport Optimisation Steering Group (PTOPS) held on 16 November 2020	Members of the state government’s PTOPS committee including from DoT, MRWA, Treasury and PTA
Digital journey planning impacts on patronage	‘Lunch and learn’ presentation – face-to-face and online held on 2 December 2020	Over 30 participants from primarily DoT and PTA
Adapting strategic road asset management practice to account for uncertainty relating to CAVs	Online seminar: The Nexus between Strategic Asset Management practice and Connected Autonomous Vehicles (CAVs) held on 16 December 2020	Around ten representatives from DoT, MRWA and some participants of the policy Delphi eg ARRB
Prioritisation of infrastructure investment proposals in the face of uncertainty	Key stakeholder face-to-face presentation and discussion held on 24 September 2020	Around ten representatives from DoT, PTA, Metronet, MRWA and IWA

4.3. PATREC PSS platform visualisation

The PATREC Planning Support System (PSS) online platform (originally developed as part of the RailSmart Smart Cities and Suburbs project) has been further augmented to contain the outputs of the ‘Understanding Patronage Trends’ research project for exploration and use (https://beta.railsmart.patrec.org/). New data layers and a hub visualisation tool have been included.

The new data layers included in the platform are:

- **Population density**: the number of under 20's/over 60's/all persons per square kilometre in each suburb for the years 2015 to 2018 inclusive, sourced from the ABS.

- **Residential vacancy rate**: the percentage of residences vacant in each suburb for the years 2015 to 2019 inclusive, sourced from SQM Research.

- **Petrol prices**: the average sale price of unleaded petrol, in real terms (referenced to 2012) for all petrol stations in the suburb or nearest suburb with petrol stations, for the years 2015 to 2019 inclusive, sourced from FuelWatch.

- **Arterial road congestion**: the weighted average speed of measured locations on the Main Roads network in each of PATREC's '15 Zones' for the years 2015 to 2019 inclusive, sourced from Main Roads.

- **Arterial road vehicle kilometres**: the total vehicle kilometres travelled on the Main Roads network in each of PATREC's '15 Zones' for the years 2015 to 2019 inclusive, sourced from Main Roads.

- **SmartRider - trip legs**: a trip leg is defined as a component of a public transport journey that begins with boarding a service and ends with alighting the same service. The number of legs taken by SmartRider users in each suburb for the years 2015 to 2018 (as is the case for all SmartRider data layers described below) are detailed. This is split by the ticket type – standard, student (all types), senior and concession (all other concessions), the time period (either weekday or weekend) and the directionality (whether measured from where boarded – origin or alighted – destination). This data is sourced from the PTA in the suburb origin-destination format.

- **SmartRider – journeys**: a journey consists of a series of trip legs which is limited by the fare rules (either 2hrs or 3rs depending on distance) to approximate the journey between an origin and destination on the public transport system. The number of journeys taken by SmartRider users in each suburb for the years 2015 to 2018 are detailed. This is split by the ticket type – standard, student (all types), senior and concession (all other concessions), the time period (either weekday or weekend) and the directionality (whether measured from where first boarded – origin or last alighted – destination). This data is sourced from the PTA in the suburb origin-destination format.

- **SmartRider - journey to service ratio**: the Journey to Service ratio divides the number of journeys as detailed above by the number of services which run through the suburb in the specified time period. This is split by the ticket type – standard, student (all types), senior and concession (all other concessions), the time period (either weekday or weekend) and the directionality (whether measured from where first boarded – origin or last alighted – destination). This data is sourced from the PTA in the suburb origin-destination format.

- **SmartRider - estimated average fare**: the estimated average fare (fare at the time in nominal dollars) is determined through modelling of the fares between suburb pairs for each set of journeys and multiplying them by the number of journeys taken. This is split by the ticket type – standard, student (all types), senior and concession (all other concessions), the time period (either weekday or weekend) and the directionality (whether measured from where first boarded – origin or last alighted – destination). This data is sourced from the PTA in the suburb origin-destination format.

- **SmartRider - estimated passenger kilometres**: the estimated passenger kilometres are calculated by multiplying the centroid-to-centroid road distance between suburb pairs by the number of journeys taken between them. This is split by the ticket type – standard,

student (all types), senior and concession (all other concessions), the time period (either weekday or weekend) and the directionality (whether measured from where first boarded – origin or last alighted – destination). This data is sourced from the PTA in the suburb origin-destination format.

- **SmartRider - average journey length**: The average journey length is calculated by calculating the total estimated passenger kilometres and dividing by the number of journeys. This is split by the ticket type – standard, student (all types), senior and concession (all other concessions), the time period (either weekday or weekend) and the directionality (whether measured from where first boarded – origin or last alighted – destination). This data is sourced from the PTA in the suburb origin-destination format.

- **GTFS - number of services**: the number of services details the average number of scheduled services which traverse the suburb by the specified time period – weekday or weekend for the specified mode – bus or train. This is sourced from Transperth's public GTFS data.

- **GTFS - service kilometres**: the total network kilometres travelled by all services in the specified time period (2015 – 2019) per suburb – weekday or weekend for the specified mode – bus or train. This is sourced from Transperth's public GTFS data.

Accessing the hub visualisation tool including activity trend and passenger churn analysis in the platform, is explained in sections 6 and 7 of the user guide (Appendix).

The version of RailSmart containing these datasets is different to the original RailSmart developed for use in planning of Yanchep Rail Extension stations in association with the DoT and the City of Wanneroo. A user guide has been produced to help inform use of the new resources within the new version of RailSmart (Appendix A).

5. Policy impacts

5.1. Factors influencing public transport patronage trends

This research was undertaken in order to inform the enhancement of the public transport patronage forecasting model for the improved prediction of fare revenues, operating subsidy requirements, levels of service provision and service innovations as well as to facilitate the development of a range of customer centric initiatives to optimise (public transport related) travel behaviour.

"Phase 1 provided detailed and novel modelling of patronage updating existing forecasting elasticities estimates for use in operational patronage models. The outputs of this research are feeding into fare review proposals being led by the PTA and Treasury.

Phase 2 delved more deeply into the impacts spatially and variations across different user profiles and transport hubs. This approach was justified and provided evidence of significant spatial and temporal variability. Phase 2 outputs will be available on the RailSmart platform to spatially inform transport planning decisions.

The research has not resulted in development of customer centric initiatives to optimise public transport use but increased understanding of factors required to influence patronage may be used to feed into customer sentiment and perception market research work being undertaken by the Department" (Jane Millar and Claire Thompson, Department of Transport, email 17 December 2020).

5.2. Digital journey planning impacts on patronage

The research was intended to inform planning and decision-making processes throughout the Transport Portfolio, particularly digital journey planning services, MaaS, travel behaviour change, public transport optimisation with associated business case development and project prioritisation.

“The research identified the reach of journey planners into everyday travel decisions for the Perth population, hence the importance of this area of investigation for influencing travel choices. Findings have been shared within the Portfolio to inform ongoing development of the Transperth Journey Planner and provides a base-level understanding of journey planner functionality for the future needs of Mobility as a Service - related policy and initiatives” (Jane Millar and Claire Thompson, Department of Transport, email 17 December 2020).

“Well done on the presentation Tristan. I had a few people come up and say how interesting it was” (Jane Millar, Department of Transport, email 3 December 2020).

5.3. Adapting strategic road asset management practice to account for uncertainty relating to CAVs

The findings of this research were intended to offer a strategic perspective on how to rethink the way transport infrastructure assets facilitate the delivery of services into the future; and how to plan for and manage transport infrastructure assets in the future.

“In terms of the 3 reports, from an asset management practitioner’s perspective, I consider the reports to be useful. The Literature Review with its findings gives a comprehensive picture of the status of CAV uptake in Australia and overseas and identifies potential impact in the six asset management areas selected. The Impact assessment via the Delphi process followed by focus group discussion was a sound approach to identify the differences, if any, between the two uptake scenarios, and it was also a reflection of people’s perception of the future at a point in time. It would had been better if more people were involved in this stage, but we need to also note this happened at the peak of the pandemic in Australia. The final report provides a good summary of the findings, highlighting opportunities in terms of CAV uptake improving asset management outcomes.

Considering these reports are for asset managers and not for CAV experts, I do consider they fulfilled their purpose. The main aim of the reports was to highlight areas of potential impact, not to delve into the details of the impact” (Flori Mihai, Main Roads WA, email 22 December 2020).

5.4. Prioritisation of infrastructure investment proposals in the face of uncertainty

The research is intended to support the Transport Portfolio in considering future uncertainties within their project assessment and prioritisation framework to ensure that their advice to the decision makers considers potential future changes to the transport systems. This research is intended to complement other initiatives within the Transport Portfolio including the update of the Investment Decision Framework.

“This report has demonstrated to the investment planning teams across the Transport Portfolio that there are ways to improve the prioritisation of investments in the face of unknown outcomes caused by future uncertainty associated with mobility and transport.

We need to prepare for and model scenarios into base cases and project cases. Even doing this as a sensitivity test will deliver a greater level of confidence that projects will deliver maximum value given an uncertain transport future.

A new Perth Transport demand model is being planned and the work from this research project will identify scenario requirements to build in this new model" (Des Lock, Department of Transport, email 22 January 2021).

6. Recommendations for further research

Understanding the changes in patronage on public transport does not tell the whole story of transport utilisation, as trips may not have shifted from PT to private vehicle, but may have shifted to modes such as walking and cycling (which can integrate well with PT), mixed-mode trips, new modes of transport (such as rideshare) or may not have occurred at all, due to teleworking and job losses. Therefore, it is vital to take private transport modes into account.

Journey planning enhancements could be informed by further research into the provision of data in new and novel formats. While this could take many forms, one popular format that has been used by other transport operators – notably airlines including Virgin Australia and Qantas – is integration with 'smart speaker' assistant systems such as Amazon Alexa to provide information regarding transport services, or alternatively Google Assistant or Siri. As such, integrating data with third-party apps or providing this as a first-party service will enable an easier interaction with public transport or active transport systems by transport users.

Further investigation into the provision of pre-booking of public transport including integration with Apple Pay and Google Pay is also an area for future research in relation to improvement in journey planning. Pre-booking a service, while separate to this, can be integrated with such digital wallets to reduce the friction of public transport usage and also to provide one component of a mobility-as-a-service system.

In addition to CAV, MaaS and micromobility are rapidly expanding markets, supported in many countries by government policies (e.g in Paris where during COVID 19 traffic lanes were repurposed for micromobility, mostly bicycles (Lagadic, 2020). COVID 19 has tested, among other things, the resilience of the transport system, which was required to accommodate a sudden and disruptive change in transport behaviour. The resilience of the transport system is ensured by having multiple, well-connected transport options. CAV uptake, MaaS and micromobility and their interaction will lead to the need to reconsider the utilisation of the transport space. There is a research need to provide evidence to inform asset managers, who will have to make sense of this complex environment, where CAV uptake is only one element, and develop policies and strategies to reflect the reutilisation of the transport space and intermodal connectivity.

To best deal with the uncertainties of future mobility in transport infrastructure investment appraisal processes, regularly conducting detailed analyses of status quo and emerging trends based on recent historical data is crucial. Additionally, the use of triggers is recommended, which would be useful to flag potential loss of utilisations without the detailed analyses of emerging trends. Further work on analysing transport demand trends and forecasting that can feed into developing more comprehensive scenarios would improve the capability and comprehensiveness of the proposed methodology.

Considering the current circumstances of COVID-19, which created such a shock in health, economy and transport, an investigation of the effect of unexpected crises could be undertaken in future stages of the research, provided that data becomes available.

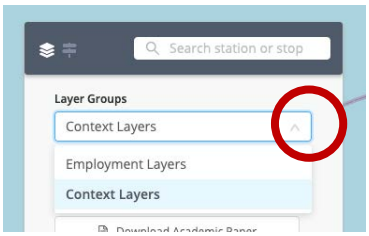
Appendix A: User Guide for viewing data layers on PATREC PSS platform (extension to RailSmart)

The RailSmart platform has been further augmented to contain the outputs of the 'Understanding Patronage Trends' research project for exploration and use. The version of RailSmart containing these datasets is different to the original RailSmart developed for use in planning of Yanchep Rail Extension stations in association with the DoT and the City of Wanneroo.

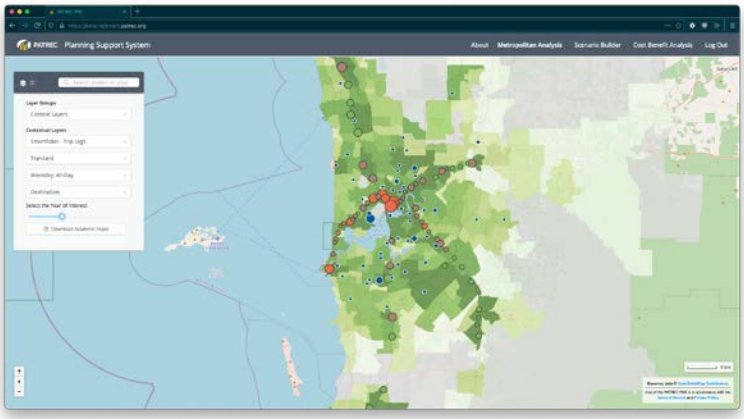
As such, this user guide has been produced to help inform use of the new resources within the new version of RailSmart. Please follow the instructions below to use the new version of RailSmart.

1. Navigate to https://beta.railsmart.patrec.org/. You will be required to log in with your RailSmart credentials. If you have forgotten these, please contact Tristan (tristan.reed@curtin.edu.au) who can provision new credentials to you.

2. Once you have logged in, you will notice the look and feel has changed since the last version of RailSmart. Select the Layers icon as shown below to view the layer picker. Then, select the 'Context Layers' option.

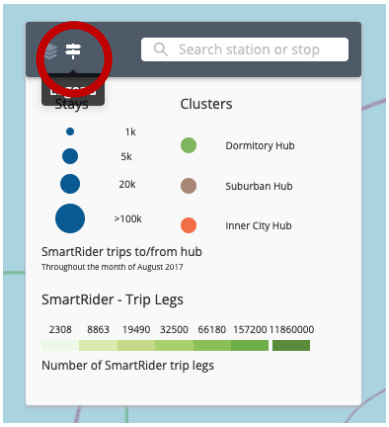


3. Select one of the layers from the list below. Some of these layers are unchanged from the earlier version of RailSmart and will function the same. Consult the appendix to this document for the layers which have been added. These new layers will generally have one or more options which must be selected first before the layer is shown, alongside a time slider which also must be set. Details of these are in the appendix but select the options you are interested in. Once all options are set, the choropleth map will appear on the right hand side on the 'main map' interface as seen below.



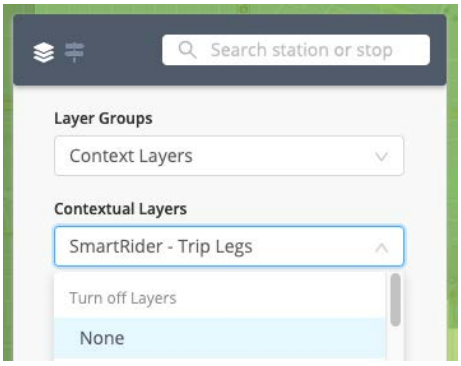
You may wish to consult the Map or Legend for more details about this data layer. To view the Legend, click the Legend icon on the top-left. The top legend refers to the station 'dots' seen

in the interface; you are interested in this case of the second legend at the bottom of the box which will describe the colours and data of what just appeared.

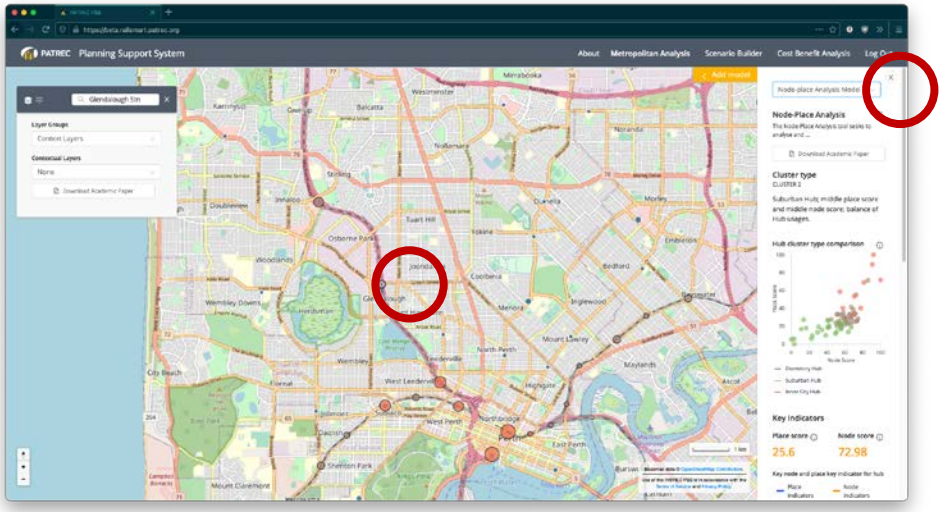


4. Alternatively, you can see the exact value of the data for an area by clicking on the area itself. You will need to double-click on a shaded/coloured map area rather than single-click.

5. You can turn off the overlay layer if desired by selecting the 'None' layer from the layer toolbox as seen below.



6. Two additional tools have also been provided: the Activity Trend Model and Passenger Churn Model (hub visualisations). These are selected the same way as models before, by clicking a station hub and then the drop-down that appears in the toolbox on the right.



7. You are then free to interpret the results within the tool and to click another station hub to compare its results.