



ANNUAL REPORT 2021

Planning and Transport Research Centre

April 2022



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Prepared by

Sharon Biermann

Version control

FINAL

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.

Publisher

Planning and Transport Research Centre
The University of Western Australia (M087)
35 Stirling Highway, Crawley, WA 6009
+61 8 6488 3385
patrec@uwa.edu.au
<https://patrec.org/>

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1. INTRODUCTION

1.1. Purpose

The primary purpose of this report is to provide an update of activities conducted in 2021 with a focus on outputs and outcomes achieved. While COVID-19 restrictions continued to curtail any face-to-face connection events and conference activities, research activities proceeded without undue interruption.

1.2. 2021 in Focus

Key achievements in 2021:

- Overall stakeholder satisfaction rate of 92.3% achieved in the annual satisfaction survey, the highest in the six years that the survey has been run
- Accolades for completed projects
 - “PATREC authors had close interactions with the DPLH CUBE Land team to gain some in-depth understanding of the CUBE Land model, while also providing us with many technical advices for further model development... encourage[d] the DPLH team to continue the advancement of the CUBE Land model implementation... provid[ing] a list of ten suggestions for such undertakings. One of them includes the estimation of non-residential models for forecasting employment distribution while acknowledging the difficulties in obtaining the required data. This has become DPLH team’s main focus in the next stage of the Cube Land model implementation” (Simon Zheng, Principal Economic Forecaster, DPLH, email 29 July 2021)
 - “I am very impressed with the analysis [Use of automated video analytics on Principal Shared Paths], particularly the manner in which the O-D volumes and speed profiles have been communicated. Please thank your team for me. The heatmaps are very impressive too... I am beginning to understand the huge potential of this technology. I am confident our client MRWA will feel the same way after reading the report” (James Pearse, Associate Transport Engineer/Team Leader, WSP, email 22 Dec 22).
“Craig [Wooldridge] and I had a quick discussion about the draft report this morning. Our overall thoughts were extremely positive in regard to the format and content within” (Colin De Costa, Project Development Officer, Main Roads, email 2 Feb 22)
- Commencement of five new PATREC core research projects from the 2021-2023 core research program
- Completion of two remaining core research projects from the iMOVE-PATREC core research program (2019-2021)
 - Enhanced land use inputs to strategic transport models through advanced econometrics (iMOVE, DPLH, Main Roads, DOT, UWA) (\$75k)
 - Modelling perimeter controls based on macroscopic fundamental diagrams (Main Roads, UWA) (\$102k)
- External projects significantly progressed or completed
 - iMOVE
 - Smart Transport Technology Roadmap Project (RAC, UWA) (\$200k)
 - Working from Home: Changes in Transport Demand (DOT, Main Roads, UWA, Curtin) (\$240k)
 - AI-assisted Model Calibration for Real-time Traffic Simulation (Main Roads, Aimsun, UWA) (\$400k) - commenced
 - AURIN/Australian Research Data Commons

- Australian Transport Research Cloud (Uni Melbourne, UWA, Curtin) (\$450k)
 - AURIN national transport domain specialist – Sae Chi 0.5 FTE appointment (Uni Melbourne) (\$98k) - commencing
 - ARC Linkage participation
 - Map My Say (AUDRC, UWA) - underway
 - Main Roads WA
 - Extension to Drone Video Analytics (UWA) (\$40k) – completed
 - Multi-Objective Genetic Algorithm Optimisation for Network Widening and Maintenance Scheduling (UWA) (\$120k) - completed
 - Consulting
 - WSP - PSP application of video analytics to cyclists and pedestrians - sub-contract to WSP (for Main Roads) (\$38k) - completed
 - Trial of the collection and automatic identification of light pole assets using machine learning (Main Roads) (\$25k) - completed
- New external projects under development
 - Freight vehicle signal priority for heavy freight vehicles trial – aligning with a trial being undertaken by TfNSW (iMOVE, Main Roads)
 - (iMOVE, Main Roads, UWA) – scoping underway
 - Improved Roundabout Modelling using Drone Video analytics (iMOVE, Main Roads, Aimsun, UWA) (\$392k) – finalising agreement
 - Innovation Connection (Metrocount) – Video analytics application (UWA) (\$100k) – finalizing agreement
 - Perth Transport Model tender with large consulting firm – shortlisted, proposal submitted
 - Application of Biochar Waste in Pavement Design - capturing carbon in pavements (Main Roads, UWA) – under discussion
 - Application of drone video analytics to fixed cameras (Main Roads, UWA) – under discussion
- 6 peer-reviewed journal articles published
- Teaching and training
 - Advanced econometric training course delivered as part of project: Enhancing land-use inputs to strategic transport models through advanced econometrics
 - Director delivered:
 - two, 2 hour lectures on transport geography and planning to around 100 undergraduate students as part of UWA’s BSc Geography program – Urbanisation and Sustainability
 - online guest lecture: Building resilient transport infrastructure and systems - part of a core unit - The Sustainable Development Goals (ENVT5518), offered in both the Master of Environmental Science and the Master of International Development, UWA
 - Transport engineering unit delivered by Chao Sun as part of UWA’s Civil Engineering course
 - Post-graduate supervision:
 - PATREC-iMOVE PhD top-up scholarship awarded - Chao Sun successfully attracted a top-performing maths and computer science PhD student: Samson Ting (Topic: Using a data-driven approach to improve intersection modelling)
 - PATREC co-supervised (ongoing) 4 PhD students (Chao Sun,) and 2 Masters dissertations (Chao Sun, Sharon Biermann)

2. RESEARCH PROJECT ACTIVITY

2.1. Projects completed

Two remaining core research projects from the iMOVE-PATREC core research program (2019-2021) were completed:

- Enhanced land use inputs to strategic transport models through advanced econometrics (\$74,6k; DPLH, Main Roads, DOT, UWA)
- Modelling perimeter controls based on macroscopic fundamental diagrams (\$102k; Main Roads, UWA)

Four external projects, not using PATREC core funds, were substantially completed with some receiving additional funding allocations from agency partners (Main Roads, UWA)

- Main Roads WA
 - Extension to Drone Video Analytics (UWA) (\$40k) – completed
 - Multi-Objective Genetic Algorithm Optimisation for Network Widening and Maintenance Scheduling (UWA) (\$120k) - completed
- Consulting
 - WSP - PSP application of video analytics to cyclists and pedestrians - sub-contract to WSP (for Main Roads) (\$38k) - completed
 - Trial of the collection and automatic identification of light pole assets using machine learning (Main Roads) (\$25k) - completed

Significant interim outputs of multi-year external projects

- WFH wave 1 report
- RAC roadmap – report
- ATRC?

The key findings of the completed core-funded projects/milestones are summarised next.

Enhancing land-use inputs to strategic transport models through advanced econometrics (completed)

PATREC-iMOVE CRC Project 1-023 (\$74,600; June 2020 – May 2021; UWA, DPLH, MRWA, DOT)

Working interactively with the CUBE Land team at DPLH, the aim was to look “under the hood” at the land use forecasting model to identify and implement some key actions to improve the quality of the land use outputs which are a key input to transport models. Comprised two parts:

- Delivering an advanced econometric training course
- Conducting a best practice international review of the bid-rent model

Advanced econometric training course

The aim of the training was to provide insights into specialised robust spatial models in support of the process of producing more reliable parameter estimates for the CUBE Land modelling platform. Although the training was focussed on generic applied econometrics, addressing time and spatial aspects (thus useful for land-use and transport forecasting), several topics covered were directly relevant to the current CUBE Land model implementation.

The intensive program was delivered face to face and fully supported by the learning management system (LMS) Blackboard at UWA.

There were 10 participants from PATREC partners who participated in the 30 hour program over four days, commencing on 13 November 2020. Four instructors delivering the materials.

The program achieved its objectives in terms of offering insights in the state-of-the-art spatial modelling in R and strengthening the links academia-government.

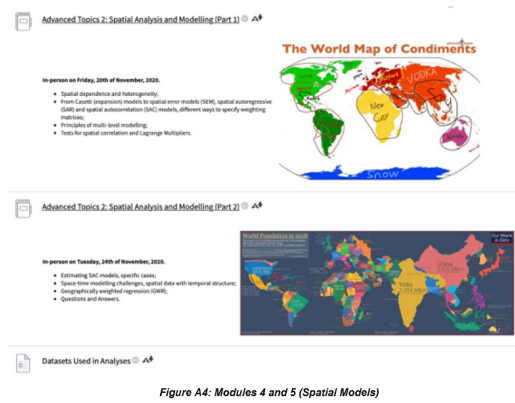


Figure A4: Modules 4 and 5 (Spatial Models)

TRAINING PROGRAM

Introduction to time series (13/11/20)	Advanced topics 1 Choice models (17/11/20)	Advanced topics 2 (Spatial analysis) (20/11/20 and 24/11/20)	
Time series (TS) structure and decomposition (e.g., air pollution measurements)	Panel data Differences between logistic regression and choice modelling Revealed and preference data	Spatial dependence and heterogeneity	Estimating SAC models, specific cases
Using regression to model univariate time series (trend, seasonality, cycle), use of lagged variables, etc.	Random utility models Discrete choice, ranking, best-worst data and model setups	From Casetti expansion models to SEM, SAR, SAC models Different ways to specify weighting matrices	Space-time modelling challenges Spatial data with temporal structure
<i>Lunch break</i>			
Smoothing techniques, autocorrelation and heteroscedasticity in TS, stationary models (ARIMA)	Multinomial (MNL) model Violations assumptions MNL	Principles of multi-level modelling	Geographically weighted regression (GWR)
Revision probability distributions ('Not everything is Normal!') and hypothesis testing	Estimation MNL (including covariates)	Tests for spatial correlation	Q&A
Excel and R exercises	NLogit, Apollo/R exercises	R exercises (estimate models in R)	R exercises (estimate models in R)

Best practice international review of the bid-rent model

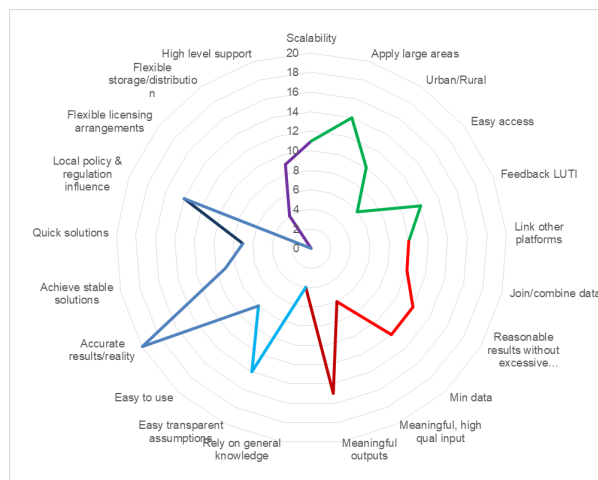
The PATREC team worked with Department of Planning, Lands and Heritage (DPLH) colleagues in examining and testing new models used in CUBE Land that apply different segmentations, use different assumptions/models/parameters, and/or account for spatial effects. This co-creating approach was adopted to jointly identify areas for improvement in the local application and set-up of CUBE Land. The approach aimed to provide practical guidance, with testing, on changes to enhance parameter estimates, convergence, or other processes in the CUBE Land modelling platform. The guidance was further informed through a best practice review and survey of current users of CUBE Land undertaken at the beginning of 2021.

Comprised three related activities:

- review of academic and grey literature
- international user survey
- collaborative exploration of the CUBE Land model as applied in Perth and Peel, WA

Recommendations to enhance the performance of CUBE Land, emanating from the findings of the literature review, user survey and collaborative exploration and testing of the CUBE Land application in Perth and Peel relate to:

- Change predictors to cost function
- Replace rent by a more fitting real estate valuation and change predictors of rent
- Adopt a more refined household composition
- Reduce adjustment factors
- Check outliers
- New approach to hard constraints
- Estimation of non-residential models
- Sensitivity analysis
- Cross-validation
- Additional connections



Modelling perimeter controls based on macroscopic fundamental diagrams (completed)

PATREC-iMOVE Project (\$102,000; December 2020 – February 2022; UWA, Main Roads)

In our previous project (iMOVE 1-003), we numerically simulated perimeter control (gating) based on macroscopic fundamental diagrams (MFDs). The results demonstrated the benefit of gating and how the Perth road network could be optimally divided into multiple zones for this purpose. As the next step towards operationalising it in Perth, this follow-up project aimed to extend the work by more detailed simulation of traffic behavior and gating strategies.

Objectives:

- Further development and confirmation of the theoretical proof-of-concept of application of perimeter control based on MFDs at the zonal level, through better and more detailed modelling
- Better understanding of potential benefits and wider implications including possible challenges
- Comparison of different controller logics and their pros and cons
- Formulation of feasible gating strategies such as changing phasing plans

Significant findings:

- Simulation data suggest that the Perth CBD can be divided into zones with well-behaved MFDs;
- Perimeter control can be applied to reduce congestion in a protected zone with the cost of increased delays at the gates;
- Type and strength of perimeter control can be modified to alter the balance between reduced congestion inside and increased delays to enter;
- If the increased flow inside the system outweighs the delay imposed at the perimeter, the overall performance can be improved using perimeter control;
- Results show that existing traffic lights can be used as gates if the controller can dynamically reallocate green times;
- Recommend reconfiguring the perimeter lights to split-phases during the control period (AM peak) but the system could also work using existing phases although it is more difficult to set up and ongoing monitoring might be required;
- Found that network flow can be increased by 39% and trip completions can be increased by 17%.

By keeping the whole network at a steady state, gating has the potential benefit of maximising the total productivity and reducing the need for local capacity expansions. This provides social, economic, and environmental benefits by improving traffic conditions for drivers using existing infrastructure which reduces required future infrastructure spending.

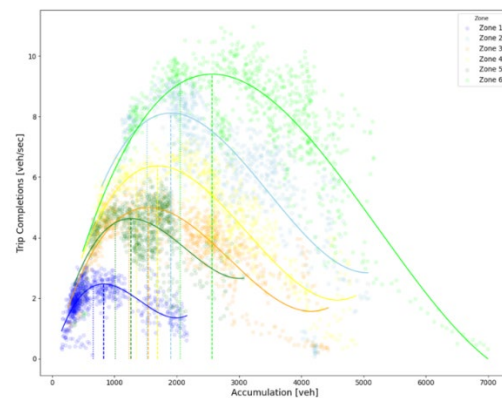


Figure 8: MFDs Generated for Six Zones

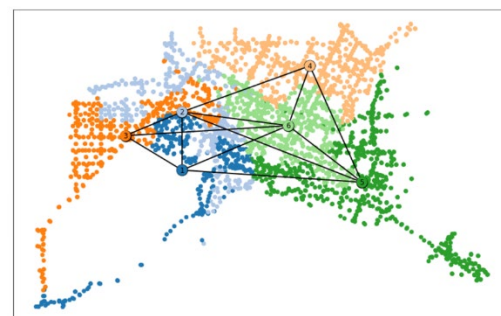


Figure 5: MFD Zones Generated using Multi-Objective Graph Partitioning Algorithm

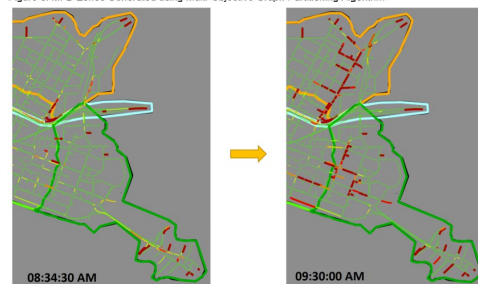


Figure 18: Congestion builds up (shown as red sections) when the Hard-Gating Multi-Zone Controller is applied

Multi-objective genetic algorithm optimisation for network widening and maintenance scheduling (completed)

PATREC External Project (\$120,000; November 2019 – April 2021; Main Roads, UWA)

To develop a prototype Multi-Objective Genetic Algorithm (MOGA) for planning works across the WA road network. A Genetic Algorithm (GA) is a robust optimisation technique inspired by natural evolution. It is widely used by computer scientists to find high-quality solutions for difficult problems such as scheduling. MOGA is a class of GA that is designed to deal with projects that have conflicting goals, e.g. minimising cost while maximising performance, which means they cannot be simultaneously optimised. A MOGA produces a frontier of solutions that represents the best trade-offs between these goals, from which the user can choose the preferred option.

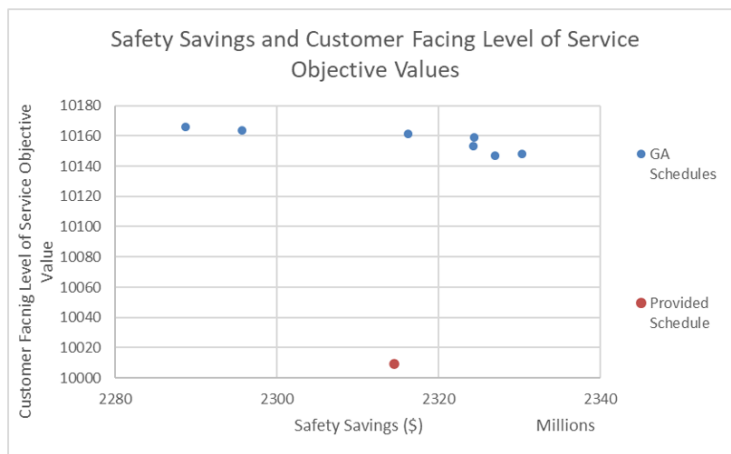


Figure 3: Comparison between GA Schedules and Provided Schedule

This project focused on the use case: joint scheduling (in terms of locality and timing) of network widening and maintenance works over a ten-year period.

Based on achieving objectives of:

- road safety
- overall cost
- road user experience
- asset condition.

MOGA minimised costs by integrating works while improving road user experience and safety by targeting the highest benefit roads.

Use of automated video analytics on Principal Shared Paths (completed)

PATREC External Project (\$38,000; September 2021 – January 2022; WSP (for Main Roads), UWA)

To conduct video surveys at six locations on Perth's Principal Shared Path (PSP) network to provide insights into how pedestrians and cyclists use PSPs (speed, volume, behaviour) at the six nominated sites and to serve as a proof-of-concept for using video surveys as an alternative to pneumatic tubes

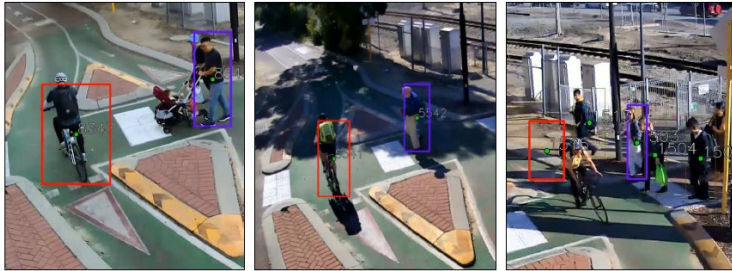


Figure 18: Cyclists failing to give way to parents pushing a pram (left), an elderly person (middle) and a crowd (right) (City West Station Precinct)

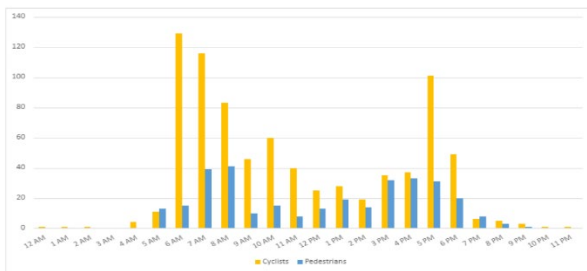


Figure 47: Cyclist and pedestrian hourly counts for the Mosman Park Station Precinct (Tuesday 14th September 2021)



Figure 91: A very close encounter between a cyclist and a car (Victoria Street Station Precinct)

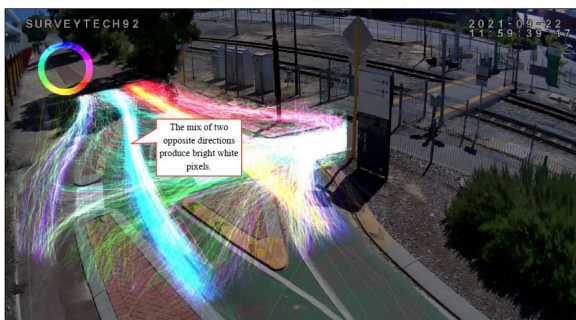


Figure 2: Example heatmap (City West Station Precinct)

Measured and identified:

- number of pedestrians and cyclists
- speeds of cyclists and vehicles
- conflicts between cyclists, pedestrians, vehicles
- give-way compliance
- incidence of crashes and near misses

Observations:

- many cyclists have probably gone too fast - speeds (85th percentile speeds) were close to or over 30 km/h
- City West Station Precinct is the busiest during the week, with the highest total volume of 3602 pedestrians and cyclists - almost equal share between cyclist and pedestrians
- Give-way compliance rate is very low
- East Perth and Victoria Street station precincts have significant issues with the way pedestrians and cyclists interact with vehicles

Performance:

- Automated video analytics program generally achieved reasonable accuracy compared to manual validation
- Shadows and camera angles caused some detection problems

Working from home travel impacts (significant milestones completed)

PATREC-iMOVE Core/External Project (\$240,000; November 2020 – May 2022; DPLH, Main Roads, DOT, UWA, Curtin)

To ascertain the extent to which WFH has been undertaken and will continue to be; the productivity impact when WFH is compared to the workplace, from the perspectives of individuals, employers, and the economy at large; the proportion of reduced travel demand that is attributable to WFH; the utility of WFH as a future demand management tool for the mitigation of congestion on all transport networks; the potential for higher levels of WFH to enable expansions of the transport network to be deferred or avoided; and the facilitation steps that would be required if it became desirable to expand the level of WFH in the longer term.

Two significant milestones completed:

- Employee perspectives on working from home – Wave 1 survey results (Milestone 2.2)
- Employer Perspectives (Milestone 2.1)

Employee perspectives on working from home – Wave 1 survey results

To conduct the first wave (of three) of the employee online panel survey to ascertain employee perspectives

Wave 1 was in the field from 14 May 2021 to 24 June 2021, between two short snap lockdowns in WA, but with very few cases and a time of low infection rates across the country. The survey comprised three modules: travel, work, and socio-economic characteristics, including personality and values. Of the 2799 Western Australians who completed at least one module, 1923 completed the travel module and 1456 completed all three modules.

Key findings:

- 68% worked from workplace, 25% hybrid (25%), 7% from home
- Hybrid workers spent an average of 1.5 days WFH and the remainder in the workplace
- Average commute days per week decreased from pre-COVID-19 (4.31) to 'last week' (3.96)
- Busiest commuting day is Wednesday
- No significant change in mode share between pre-COVID-19 and 'last week', although car and active travel increased the share by 1–2%, and public transport ridership decreased
- Those in the most flexible occupations (Managers; Professionals) had the highest proportion of WFH (22.1%) and the lowest commute rate (3.86 commute days per week)
- Those in the frontline occupations had the highest commute rate (4.11)
- Hybrid workers reported a higher level of scheduling autonomy and vigour, but also higher home–work conflict, close monitoring and loneliness than those working at the workplace
- Current proportion of WFH and occupation type (frontline workers) were the strongest predictors of future % hours of WFH
- Current % hours WFH was a significant indicator of future WFH
- % hours WFH significantly reduced commuting
- Total number of working hours and home–work conflict was related to increased commuting

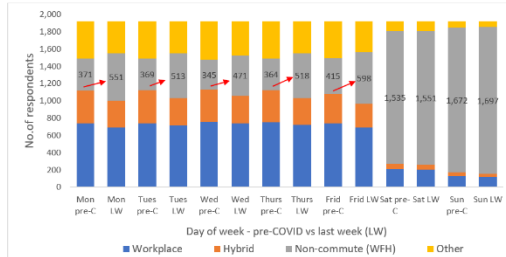


Figure 7: Place of work by day of week, pre-COVID-19 and 'last week'

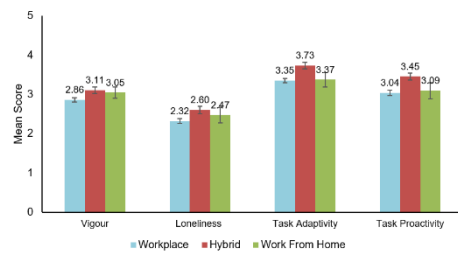


Figure 16: Significant mean differences between work locations for work wellbeing and performance

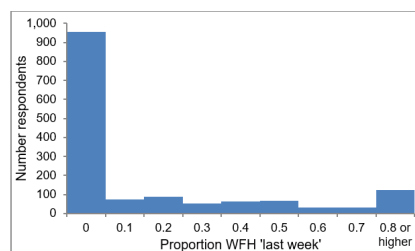


Figure 5: Sample distribution of the % of WFH hours during the 'last week'

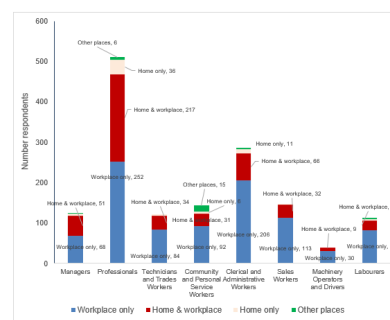


Figure 8: Distribution employees by occupation and place of work (N=1456)

Employer Perspectives

To understand employer perspectives on working from home through a series of in-depth interviews conducted with a selection of Perth-based businesses

Businesses were selected using three sources: the WA Land Use and Employment survey (conducted between 2017 and 2017) which provides a census of all businesses in WA; members of the Committee for Perth (by invitation); and by applying a snowballing technique.

The aim was to ensure representation of businesses by industry type (focussing on those that had the potential to WFH), size (number of employees) and geography (focussing in the Greater Perth area). Twenty businesses participated.

Table 3: Participating businesses by industry type

Industry type	Number
<i>Public sector</i>	
National	1
State	3
Local	3
<i>Private sector</i>	
Legal	3
Property	3
Planning and Design	2
Research and consulting	2
Finance	1
Aged Care	1
Mining	1

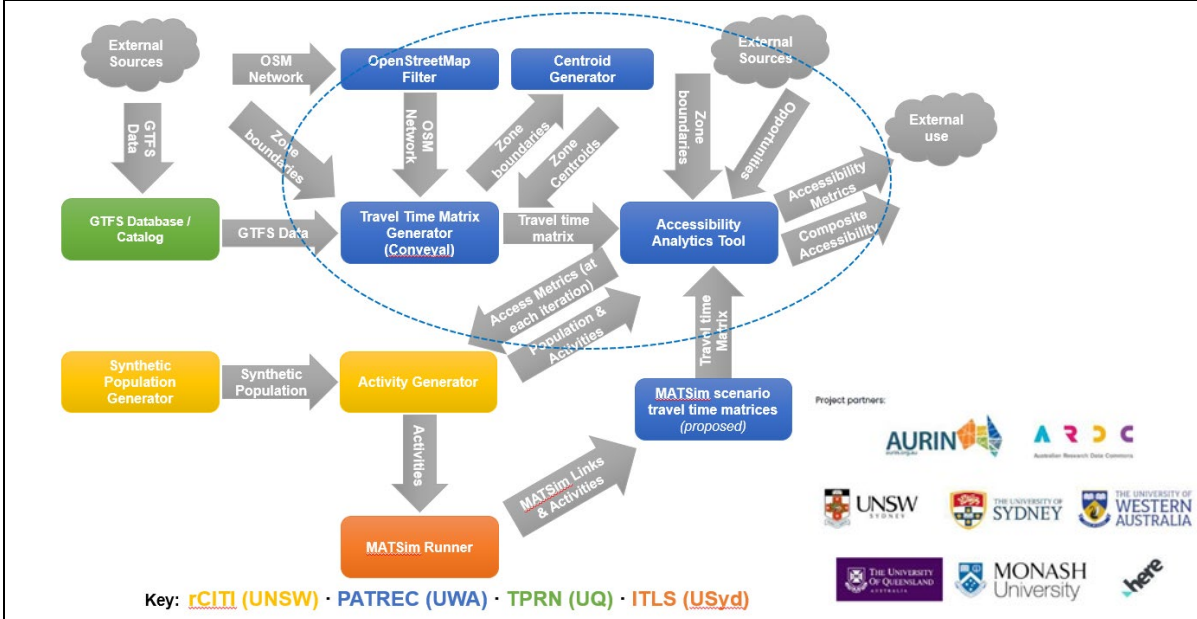
Key insights:

- Prior to the pandemic WFH practices were mainly insignificant
- WA's first lockdown saw a major shift to WFH practices
- Significant acceleration of WFH practice with almost all businesses now practicing a hybrid WFH model
- Businesses now embraced more flexible working practice, permissible to WFH on occasions
- WFH was more suited to certain types of tasks, rather than being distinguished by occupation or industry type
- Performance has not suffered as a result of WFH but concerns with over-productivity
- Staff keen on hybrid to avoid long commute
- Shift to activity-based internal floor space layouts
- Future of WFH practices appears to be a continuation of the new hybrid model, with operational policies being developed

AUSTRALIAN TRANSPORT RESEARCH CLOUD

ATRC: ADAPT Accessibility Tool (significant progress milestone completed)
 PATREC External Project (\$400,000; December 2020 – June 2023; NCRIS, AURIN, UWA, Curtin)

To provide transport researchers, planning and policy makers from academia, government and industry, with a platform that is sustainable and offers data and tools to accelerate transport research and impacts across Australia into the future. Aim is to provide a common platform (data, storage, compute and tools) to support the needs of the Australian transport research community

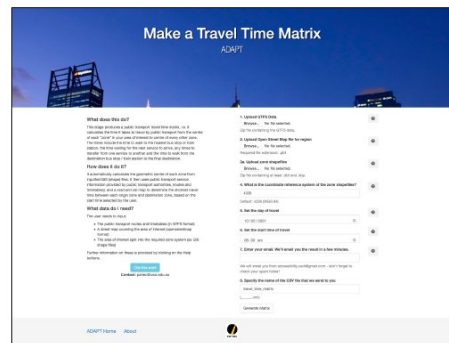


PATREC has been focusing its effort on work items within development and consultation areas:

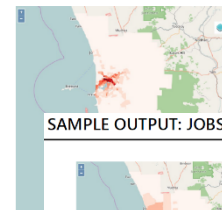
- Development work on the ADAPT tool has centred on re-writing the Accessibility Analytics and Travel Time Matrix Generator services to update/improve their codebase
- Use case development is also underway with opportunities being identified with local the TREK study and Transport Disadvantage project
- In consultation work, outside researchers were engaged to understand potential extensions to ADAPT that included discussions on a new utility-based accessibility measure that is weighted by population group and purpose
- Other engagements included discussions with ITLS regarding potential connections to their tools that can add value and support new potential flows on the platform

(Extract from ATRC
 8 December 2021
 Progress Report)

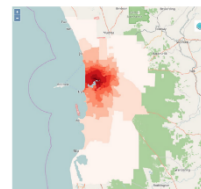
This collaborative project is led by the Australian Urban Research Infrastructure Network (AURIN) and supported by the Australian Research Data Commons (ARDC), which are enabled by the National Collaborative Research Infrastructure Strategy (NCRIS).



SAMPLE OUTPUT: JOBS BY PT (30MIN PERTH)



SAMPLE OUTPUT: JOBS BY CAR (30MIN PERTH)



Smart Transport Technology

Roadmap (significant milestone completed)

PATREC-iMOVE External Project (\$200,000; October 2020 – June 2022; RAC, iMOVE, UWA)

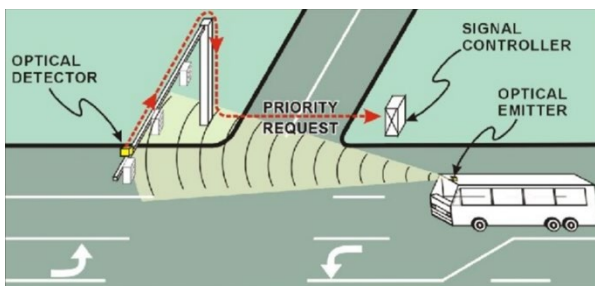
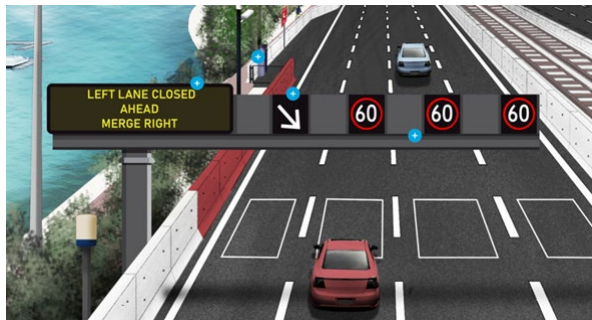
To identify promising technologies that can best address key transport and mobility challenges in Perth, Western Australia (WA) and outline a Smart Transport Technology Roadmap (the Roadmap) for the next three to five years

Strategic Analysis Report (Stage 1 (Milestone 2) deliverable completed)

Strategic analysis to identify a broad range of individual smart transport technologies available to the market and summarise their potential and likely effectiveness in a Perth context.

This report presents the results of Stage 1 (strategic analysis) including:

- a high-level analysis of the key transport and mobility challenges and opportunities for the deployment of smart transport technologies in Perth;
- an audit of currently available smart transport technologies and their likely effectiveness in a Perth context based on the experience of jurisdictions in cities across Australia and internationally;
- a roundtable was held to gain feedback on the proposed ideas and their likely effectiveness within a Perth context



Possible smart technology options for Perth identified:

- **Improved vehicle detection and signal optimisation:** a wider rollout of fit-for-purpose sensors (such as passive infrared and ultrasonic, as well as video detection) at key intersections (with unsafe and congested locations prioritised) to optimise traffic signals through existing traffic management systems (SCATS/STREAMS)
- **Pedestrian and cyclist detection and prioritisation:** rollout of fit-for-purpose sensors at key intersections and midblock locations throughout the road network to enable vulnerable road user detection (pedestrians and cyclists)
- **Public transport optimisation and prioritisation:** bus signal priority on high-frequency bus routes (including in mixed traffic) as well as the wider rollout of bus dynamic stand allocation at more bus stations (those where current capacity is an issue) for greater throughput across the bus network
- **Expansion of smart freeways:** an expanded rollout of smart freeways to more of the freeway network and/or the concept to controlled-access highways (e.g. sections of Tonkin and Roe highways)
- **Automation of camera-based enforcement:** an increase in the rollout of camera-based enforcement (such as speed, lane and red-light control) and the automation of integration between this and fine-issuing systems (such as for bus lanes).
- **All-of-network data management system for real-time network management and longer-term planning:** the connection of various sensors and other components into a single, multi-modal dashboard providing a 'whole of city view' on transportation

2.2. New PATREC core projects commenced

The new program of core-funded research projects (2021-2023), as approved at the Board meeting held on 26 November 2020, commenced with most run through the iMOVE CRC (Table 1). Detailed project plans were incorporated into project agreements and agreed by funding partners. All except one of these projects were contracted and commenced in 2021 (Table 2).

Table 1: New core projects (2021-23 program of research) commenced in 2021 (with the exception of the freight transport project)

Project title	Summary
Transport environment and kids... 15 years on (PATREC-iMOVE)	<p>Fewer Australian children walk and bike ride to school than ever before. Increasing the prevalence of active school transport is a public health priority and would result in numerous health, environmental and economic benefits. In Perth, WA, the declining rate of active school transport has been identified as a problem requiring multiple government agency responses to reverse the decline. Contributing to this initiative, this project aims to update and expand some of the metrics from the "TRavel Environment and Kids" study (TREK) conducted in Perth in 2005, including the walkability analysis of Perth metropolitan schools, traffic densities, parental perceptions of neighbourhood safety and latent demand for walking and cycling to school. Schools and neighbourhoods with the greatest need for connectivity improvements, safety treatments and programs to address parental concerns, will be identified, as well as any other insights for increasing the rates of walking and riding to school.</p>
Identifying opportunities to address transport disadvantage in Perth (PATREC-iMOVE)	<p>The provision of transport services and infrastructure to access employment, education, medical/health appointments, shopping and social activities is integral to enabling members of the community to meet their social and economic needs. Access to a wide range of opportunities contributes to economic growth and promotes wellbeing. Transport is an essential service to help meet government objectives around community access, enhancing social connectivity and addressing social exclusion and isolation. Transport disadvantage is a complex multidimensional concept relating to deficiencies in the level of transport choice and flexibility available to different population groups at various times and for various purposes.</p> <p>This project aims to identify and apply locally relevant indicators to estimate the extent, spatial distribution and nature of transport disadvantage in Greater Perth. Various measures of transport disadvantage from different perspectives (transport, community and demographic) will be analysed. Various aspects of transport disadvantage will be identified and mapped on the basis of characteristics that are particularly relevant in Greater Perth. An overview of how the transport disadvantage is affecting decisions to travel will be provided through the stakeholder interviews. A series of recommendations regarding opportunities for research and action by governments and other key service providers will be made drawing on the research findings and stakeholder interviews. The recommendations will identify the potential for new and research-informed initiatives and policy that builds upon existing approaches and local experience contributing to addressing the needs of the beneficiaries (i.e. transport users, governments and community).</p>

<p>Integrated IoT, computer vision and machine learning technologies for smarter bridge health monitoring and prediction (PATREC-iMOVE)</p>	<p>Integrated IoT, computer vision and machine learning technologies offer a promising supplement to physical bridge health assessment particularly in remote regional contexts which can be costly, time consuming and unsafe to inspect. Conducting regular, efficient and reliable bridge health monitoring is essential for the long-term protection of valuable road assets through timely maintenance responses. This project aims to investigate the feasibility of using an integrated package of up-to-date technologies, including IoT-based vibration sensors, sensing data transmission and visualization, vision-based techniques for measuring bridge displacement and machine learning techniques for relating the displacement measurement data with traffic load, to support smart bridge health monitoring and prediction. The research will produce a proof-of-concept to demonstrate the efficacy and feasibility of an integrated package of technologies for first-level bridge health screening and early warning system, reducing the need for traditional physical inspections and instrumentation. The benefits of the project include contributing to reducing maintenance, operation costs and risk, and achieving a safe transport infrastructure network, ultimately, increasing productivity.</p>
<p>A real time model for estimating delays at traffic signals (previously, value driver model) (PATREC-iMOVE)</p>	<p>Real-time information, especially delay time, is valuable for traffic operations but it is limited and costly. The existing data sources that Main Roads have access to all have their challenges in availability, cost and accuracy. This project aims at developing a pilot model that utilises secondary datasets within Main Roads (e.g. signal timing data) to estimate overall delay at each intersection in real-time. This could allow Main Roads to measure the delay at a network, intersection, or approach level, while not requiring any additional expense in data licensing agreements. It would inform project and operational decisions.</p>
<p>Machine learning models for road maintenance investment decision making (PATREC-only)</p>	<p>Road maintenance investment decisions are conventionally made by experts with decades of experience. Those experts are often occupied by a heavy workload so they often have limited time to train new staff. The aim is to develop an efficient and robust data driven decision-making model for road maintenance investment planning to improve transparency and repeatability and minimise risks. The main objectives are to:</p> <ul style="list-style-type: none"> • Develop efficient and robust data driven decision-making model for road maintenance investment planning to improve the transparency and repeatability and minimise the risk. • Capture experts' knowledge using the machine learning models including the implicit decision rules they might use.
<p><i>Adequacy of the road freight transport network to support the freight task in Australia's North West now and into the future – under negotiation</i> (PATREC-iMOVE)</p>	<p><i>This research project is intended to update freight movement forecasts with associated road freight network implications for Australia's North West, focusing on the Pilbara and Kimberley regions. Given significant changes in the resources industry landscape since the previous forecasts undertaken in 2011, there is a need to account for the substantial increases in the inbound logistics demand due to growth in the iron ore sector and resulting construction-related activities as well as future trends in commodities and renewable energy industries Accordingly, this research aims to understand the current and future flows of freight, based on an analysis of future trends in mining, oil and gas and renewable energy industries, and impacts on the road freight network. Analysing the trends in freight movement in relation to the current capacity of the roads, this study will identify potential</i></p>

	<i>constraints on the road freight network and propose strategic operational and infrastructure options to resolve the bottlenecks. This research will provide insights into the transport infrastructure needed to ensure the road freight transport network can continue to support the substantial freight task in Australia's North West, now and into the future.</i>
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Table 2: Contracting status of commencing core projects of the 2021-2023 program of research as at 31 December 2021

Project Title	Key Agency	Uni/s	Budget (\$)	Progress as at 31 December 2021
Transport Environment and Kids... 15 Years On	DoT/DPLH	UWA	100,000	Agreement executed on 15 November 2021
Identifying opportunities to address transport disadvantage	DoT (DoC)	PATREC, UWA, Curtin	99,594	Agreement executed on 14 December 2021
Freight network to support NW freight task	DoT/DPLH	ECU	84,930	Agreement under negotiation
Integrating AI and IoT based Bridge Health Monitoring	Main Roads	Curtin, UWA	270,407	Agreement executed on 5 October 2021
Realtime model of delay at traffic signals (Value Driver)	Main Roads	PATREC/UWA	120,000	Agreement executed on 24 November 2021
ML models for road maintenance investment decision making	Main Roads	PATREC	100,000	Agreement executed on 9 December 2021
Working from home travel impacts - DPLH component	DPLH	Curtin/UWA	30,000	Agreement executed 15 November 2020
TOTAL (additional \$90,931 contributed by MRWA for Bridge Health)			804,931	
PA TREC available budget			714,000	

3. KNOWLEDGE TRANSFER

3.1. Research outputs

The focus of PATREC's research outputs in 2021 was on the publication of technical reports for completed projects and as substantive milestone deliverables – eight reports were produced (Table 3). The annual Australian Transport Research Forum conference was held in Brisbane as well as online and five papers were presented online, with four accepted for publication in the proceedings which have not yet been released (Table 5). In addition, a peer-reviewed FACTBase Bulletin was published by the Committee for Perth and also presented at a FACTBase Talks online event hosted by the Committee for Perth.

Six peer-reviewed journal papers were published in 2021 (Table 3) with 11 journal papers progressed (submitted, re-submitted or accepted for publication) (Table 4). Twelve seminar/webinar presentations were given by PATREC associates at PATREC and other industry-organised events (Table 5). Three news articles and a webinar video based on PATREC-research were published on the iMOVE website with links provided from the PATREC website (Table 3).

Table 3: Research publication outputs in 2021

Publication Title	Authors	Date
RESEARCH PROJECT TECHNICAL REPORTS COMPLETED		
Enhancing land-use inputs to strategic transport models through advanced econometrics - CUBE Land Best Practice Review: Literature and User Survey	Doina Olaru, Brett Smith & Sharon Biermann	17 May 2021
The implications of working from home for transportation: perspectives, policies and prospects - literature review	Long Vo, Brett Smith & Sharon Biermann	June 2021
Employee Perspectives on Working from Home: Wave 1 survey results	Doina Olaru, Julie Lee, Caroline Knight & Sharon Biermann	22 Sept 2021
Working from Home: Employer Perspectives	Carey Curtis	22 Sept 2021
Smart Transport Technology Roadmap: Strategic Analysis Report	Tristan Reed, Doina Olaru, Farid Boussaid, Sae Chi & Sharon Biermann	August 2021
Implementing Perimeter Controls on Perth CBD	Michael Dorrell & Chao Sun	2 Feb 2022
Multi-objective genetic algorithm optimisation for network widening and maintenance scheduling	Anna Taleb-Bendiab & Chao Sun	April 2021
Use of Automated Video Analytics on Principal Shared Paths	Chao Sun, Sergio Banchemo, Daniel Demiris & James Pearse	January 2022
PEER-REVIEWED JOURNAL PAPERS PUBLISHED		
Cummins, L., Sun, Y., & Reynolds, M. (2021) Simulating the effectiveness of wave dissipation by FollowerStopper Autonomous Vehicles, <i>Transportation Research Part C: Emerging Technologies</i> , 123, p.102954		
Prior, D., Saberi, M., Janjua, N., Jie, F., (2021), Can I Trust You? Incorporating Supplier Trustworthiness into Supplier Selection Criteria. <i>Enterprise Information Systems</i> , 15(3), 1-28, London, DOI: 10.1080/17517575.2021.1878393.		
Jie, F., Standing, C., Biermann, S., Standing, S., & Le, T. (2021). Factors affecting the adoption of shared mobility systems: Evidence from Australia. <i>Research in Transportation Business and Management</i> . https://doi.org/10.1016/j.rtbm.2021.100651		
Pettigrew, S. The potential effects of autonomous vehicles on physical activity. <i>Global Health Promotion</i> 1757-9759; Vol 0(0): 1–8; 1019219.		

Olaru, D., Greaves, S., Leighton, C., Smith, B. and Arnold T (2021). Peer-to-Peer (P2P) Carsharing and Driverless Vehicles: Attitudes and Values of Vehicle Owners <i>Transportation Research A. Policy and Practice</i> , 151, pp.180-194.
Standing, C., Jie, F., Le, T., Standing, S., & Biermann, S. (2021). Analysis of the Use and Perception of Shared Mobility: A Case Study in Western Australia. <i>Sustainability</i> , 13(16), 8766. Retrieved from https://www.mdpi.com/2071-1050/13/16/8766 .
PATREC PERSPECTIVES, BULLETINS, ARTICLES, VIDEOS PUBLISHED
iMOVE news article (24 Nov 21): The TRavel, Environment and Kids (TREK) Study: 15 years on https://imoveaustralia.com/project/travel-environment-and-kids-study-15-years-on/
iMOVE news article (23 Nov 21): Transport predictive solution Stage 2: AI and real-time simulation https://imoveaustralia.com/project/transport-predictive-solution-stage-2-ai-and-real-time-simulation/
iMOVE news article (5 Aug 21): Using a data-driven approach to improve intersection modelling https://imoveaustralia.com/project/data-driven-approach-to-improve-intersection-modelling/
iMOVE webinar video: Managing Transport System Investment Risk of Changing Trends and Uncertainty https://imoveaustralia.com/news-articles/personal-public-mobility/video-managing-transport-system-investment-risk-changing-trends-uncertainty-webinar/

Table 4: Journal papers in-progress in 2021 (Submitted, Re-submitted, Under Review or Accepted for Publication)

Paper
Clements, S., Olaru, D., Smith, B., & Boruff, B. Understanding the impact of agglomeration economies on commercial property prices, <i>Journal of Transport Geography</i> . Under review
Standing, C, Standing, S, Hoffman, T, Jie, F, Kiani Mavi, R & Biermann, S. Future Trends in Freight Transport and Logistics: A Literature and Expert Analysis. <i>Transport Reviews</i> . Under review
Huang, Y., Smith, B., Olaru, D., & Taplin, J.E. On interpreting models of risk in a random utility setting, <i>Transportation Research B</i> . Under review
Kiani Mavi, R, Kiani Mavi N, Olaru, D, Biermann, S and Chi, S. Innovations in freight transport: A systematic literature evaluation. <i>International Journal of Logistics Management, Special Issue: Bridging the Research Practice Gaps in Supply Chain Management: Lessons from COVID 19</i> . Resubmitted to another journal. Under review
Martinus, K & Biermann, S. Tackling the Inherent Structural Inequality of Employment Decentralisation Policy Targets, <i>Land Use Policy</i> . Under review
Jie, F, Rashid, B, Standing, C, Biermann, S, Le, T., LAMSO-DSS: A Data-Driven Decision Support System for Shared Transport Options in Western Australia, <i>Research in Transportation Economics</i> . Submitted
Vo, L., Martinus, K. & Smith, B. A Demand Systems Approach to Understanding Medium-Term Post-Pandemic Consumption Trends. <i>Applied Economics</i> . Submitted
Cardell-Oliver, R. and Olaru, D. CIAM: a data-driven approach for classifying long-term engagement of public transport passengers at multiple temporal scales, <i>Transportation Research A</i> . Submitted
Chi, S., & Mazzer, S. Preparing for the Uncertainty of Future Mobility in Australian Transport Infrastructure Investment Prioritisation. <i>Case Studies on Transport Policy</i> . Submitted
Cummins, L., Sun, Y., & Reynolds, M., Intelligent Pick-up and Drop-off System for Passenger Vehicles. <i>Journal of Urban Technology</i> . Submitted
Ting, S., Sun, Y., & Reynolds, M., Investigating the Profitability of a Reservation-Based Demand Responsive Transport as an Alternative Business Model. <i>Transportation</i> . Submitted

Table 5: Seminars, online webinar and conference presentations

SEMINAR/WEBINAR PRESENTATIONS
<p>PATREC Working from Home Seminar – What recent evidence is telling us, held on 15 March 2021:</p> <ul style="list-style-type: none"> • Julie Lee (UWA) - The Values Project survey • Doina Olaru (UWA) - Travel Demand sub-component of The Values Project survey • Caroline Knight (Curtin) - Centre for Transformative Work Design, Working from Home survey • Carey Curtis (PATREC Adjunct) - Bankwest Curtin Working Closer to Home study • Marion Fulker (Committee for Perth) - Future of Work – Impact of COVID-19
<p>iMOVE-PATREC webinar on 11 August 2021 - Managing Transport System Investment Risk of Changing Trends and Uncertainty:</p> <ul style="list-style-type: none"> • Project overview - Enhancing patronage prediction, strategic asset management practice and appraisal processes to account for emerging trends and uncertainty, Prof. Sharon Biermann, Director PATREC, University of Western Australia • Enhanced patronage trend prediction, Dr. Brett Smith, University of Western Australia • Role of journey planning applications in influencing patronage, Mr. Tristan Reed, Curtin University • Adapting strategic road asset management practice to account for uncertainty relating to CAVs, Prof. Kerry Brown, Edith Cowan University • Adapting infrastructure project prioritisation to account for uncertainty relating to disruptive technology, Dr. Sae Chi, University of Western Australia
<p>Committee for Perth – Online Event – “FACTBase Talks”, Wednesday, 3 February 2021, Sharon Biermann and Kirsten Martinus presented: Future of Work - Making strategic jobs count</p>
<p>27 Oct 21: Associate Professor Doina Olaru, Head of Department, UWA Business School, Management and Organisations, UWA, was the Australian Computer Society (WA) 9th Annual Dennis Moore Oration speaker presenting on “Data Analytics for Smart City Transportation”</p>
CONFERENCE PAPERS PRESENTED
<p>Biermann, S and Martinus, K, (2021) FACTBase Bulletin 73, Making strategic jobs count: addressing issues of spatial inequality. February 2021, Committee for Perth. Published https://www.committeeforperth.com.au/documents/factbase-bulletin-73-making-strategic-jobs-count-addressing-issues-of-spatial-inequality</p>
<p>Reed T W & Biermann S. (2021) Lockdowns and Lags: Lessons from the effect of COVID-19 on the Perth transportation system. <i>The 42nd Australasian Transport Research Forum 2021. Presented and accepted for publication in proceedings</i></p>
<p>Vo L, Smith, B & Biermann S. (2021) The implications of working-from-home for transportation: Literature Review. <i>The 42nd Australasian Transport Research Forum 2021. Presented and accepted for publication in proceedings</i></p>
<p>Olaru, D & Smith B. (2021) Lessons for Adopting Microeconomic Land Use Models at the City Scale: Perth Case Study. <i>The 42nd Australasian Transport Research Forum 2021. Presented and accepted for publication in proceedings</i></p>
<p>Schepis, D., Purchase, S., Ellis, N., Olaru, D. and Smith, B. (2021) How Governments Influence Autonomous Vehicle (AV) Innovation <i>The 42nd Australasian Transport Research Forum 2021. Presented and accepted for publication in proceedings</i></p>
<p>Schepis, D., Purchase, S., Ellis, N., Smith, B. (2021) Autonomous Vehicle Sociotechnical Imaginaries: Stakeholder Comparison <i>Australian and New Zealand Marketing Academy Conference 2021. Presented</i></p>

3.2. PATREC connection opportunities and events

- WFH iMOVE collaborative forum presentation on 9 February 2021 – Doina Olaru presentation on longitudinal survey approach (“Just wanted to say how useful it was to have you on behalf of PATREC attend this morning’s WfH Collaboration Forum. There are so many opportunities for cross pollination and shared learning between the three projects” - Claire Thompson, DoT and WA project steering committee chair, email 9/2/21; “Doina was fantastic”, Lee-Ann Breger, iMOVE CRC Programs Director)
- PATREC seminar – Working from Home – What recent evidence is telling us, held on 15 March 2021. In conducting the working from home research, the research team built on existing research surveys and studies. The presenters, most of whom are part of the team, shared what current surveys and studies are showing and where relevant, how these would be built upon in the new project.
- A PATREC-iMOVE webinar was held on 11 August 2021 to disseminate the findings of the Risk Management project
- PATREC co-hosted the John Taplin Inaugural Memorial Lecture: What does intelligent mobility through MaaS add to sustainability? by Prof David Hensher on 17 March 2021
- Director participated as an invited Discussant in the City Analytics session of the international Applied Urban Modelling AUM2020: Modelling the New Urban World, Online global workshop, 28 January 2021, hosted by Martin Centre for Architectural and Urban Studies, University of Cambridge
<https://www.martincentre.arct.cam.ac.uk/conferences/AUM/aum-2020/aum2020-global-workshop>
- WFH iMOVE collaborative forum presentation on the employer interview results by Carey Curtis on 9 November 2021
- Research seminar: 10 September 2021 – Business School - How Governments Influence Autonomous Vehicle (AV) Innovation. Presenters: Dr Daniel Schepis and Professor Sharon Purchase
- Research Seminar: 1 Oct 21 – UWA Business School - Challenges and Opportunities in Crowdsourced Delivery Planning and Operations, Martin Savelsbergh.
- 27 Oct 21: Associate Professor Doina Olaru, Head of Department, UWA Business School, Management and Organisations, UWA, was the Australian Computer Society (WA) 9th Annual Dennis Moore Oration speaker presenting on “Data Analytics for Smart City Transportation”.
- The Director accepted a position on the Board of CUPUM - Computational Urban Planning and Urban Management (CUPUM) – this is an international group, represented by two from each continent, who promote the use of smart technology in urban planning. Other members are: Chris Pettit, Professor of Urban Science and Director – City Futures Research Centre, UNSW Sydney (Australia); Joe Ferreira, Professor Urban Information Systems MIT (North America); Robert Goodspeed, Assistant Professor Urban and Regional Planning University of Michigan (North America); Weifeng Li, Associate Professor of Urban Planning and Design, University of Hong Kong (Asia); Zhan Qingming, Professor and Director, Research Centre for Digital City, Wuhan University (Asia); Renee Sieber Associate Professor Department of Geography, McGill (North America)

3.3. Teaching and training

- PATREC worked with the Western Australian Centre for Road Safety Research (WACRSR) to explore the development of road safety and transport planning micro-credential training modules with the objective of cross-disciplinary learning and upskilling for practitioners and students. The anticipated program is intended to be designed for professional development and/or stackable modules which could be converted to academic credits. A short survey distributed to key stakeholders to elicit the level of interest and support found a high level of interest as well as priority topic areas.
- The Director repeated a guest lecture on the topic: Building resilient transport infrastructure and systems - part of a core unit - The Sustainable Development Goals (ENVT5518), offered in both the Master of Environmental Science and the Master of International Development, UWA. Sae Chi participated in the discussion with students on behalf of Director on 26 August 21.
- Teaching lectures delivered – as approved by the Board on 26 November 2020, the Director delivered two, 2 hour lecture sessions on transport geography and planning to around 100 undergraduate students as part of UWA's BSc Geography program – Urbanisation and Sustainability. The lectures were recorded and made available on the PATREC website.

<p>Session 1: Transportation - Back to the Future</p> <ul style="list-style-type: none"> ▪ PART 1 <ul style="list-style-type: none"> • Basic concepts, definitions, importance • Transport and the physical environment • Revolutionary and evolutionary transport through time ▪ PART 2 <ul style="list-style-type: none"> • Future transport 	<p>Session 2: Transport Geography, Planning and Policy</p> <ul style="list-style-type: none"> ▪ PART 1 <ul style="list-style-type: none"> • Understanding transport • Transport and spatial organisation • Transport and location • Conceptual models • Transport Planning and Policy ▪ PART 2 <ul style="list-style-type: none"> • Urban transport • Land use – Transport interaction • Managing transport • Transport economics • Sustainable and resilient transport systems
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- Chao Sun – delivered the Transport Engineering Unit as part of UWA's Civil Engineering. He was compensated for his time
- PhD student supervision: PATREC co-supervised (ongoing) 4 PhD students (Chao Sun,) and 2 Masters dissertations (Chao Sun, Sharon Biermann):
 - Samson Ting (PhD) co-supervised with Thomas Stemler - data-driven approach to improve intersection modelling (PATREC and iMOVE top-up scholarship)
 - Liam Cummins (PhD) co-supervised with Mark Reynolds - smart pick-up and drop off solution
 - Xiaoyu Lin (PhD) co-supervised with Yuxia Hu from Civil - recycled soft plastics in pavement
 - Afagh Malek (PhD) co-supervised with Cara MacNish and Mubashar Hassan from CS - public transport optimisation using SmartRider data
 - Daniel Ho (Master of professional engineering final year project), co-supervised with Mark Reynolds - short term traffic prediction
 - Michelle Winder (Master of Urban Planning – dissertation) – working from home land use impacts

3.4. Research impact

3.4.1. Research project outcomes

For completed projects, steering committee chairs/representatives provided feedback on the output quality and value for policy formulation.

Enhancing land-use inputs to strategic transport models through advanced econometrics

The intention of this research was to look “under the hood” at the new land use forecasting model being implemented by DPLH, to identify and implement some key actions to improve the quality of the land use outputs which are a key input to transport models. The research team working interactively with the modelling team at DPLH to achieve these enhancements.

Responsible for CUBE Land’s implementation at DPLH, Simon Zheng, Principal Economic Forecaster, said (email dated 29 July 2021):

- “As a part of the iMOVE project, PATREC’s report on the best practice review and survey of CUBE Land users was completed on 30 April.
- The report acknowledges that the DPLH CUBE Land team has undertaken a rigorous exploration process of CUBE Land and progressed substantially in the set-up and implementation process.
- Apart from providing the rich information on land use modelling principles and practices, the report emphasises that behaviour-based land use models, like CUBE Land, are superior to the rule-based models (like MLUFS), as the former model the choices made by households and businesses, also being capable of taking into account the effects of feedback between land use and transport system. These features seem essential for any modern land planning decision support system. This message is consistent with that from the previous DPLH-commissioned reports on land use forecast models.
- During the drafting of the report, PATREC authors have had close interactions with the DPLH CUBE Land team to gain some in-depth understanding of the CUBE Land model, while also providing us with many technical advices for further model development.
- The PATREC authors encourage the DPLH team to continue the advancement of the CUBE Land model implementation. The report provides a list of ten suggestions for such undertakings. One of them includes the estimation of non-residential models for forecasting employment distribution while acknowledging the difficulties in obtaining the required data. This has become DPLH team’s main focus in the next stage of the Cube Land model implementation.”

Modelling perimeter controls based on macroscopic fundamental diagrams

In this research we extended previous work which demonstrated the benefits of perimeter control (gating) in Perth. As the next step towards operationalising it in Perth, this follow-up project aimed to undertake more detailed simulation of traffic behavior and gating strategies in order to formulate feasible gating strategies.

Main Roads’ SCATS SME reviewed the feasibility of implementing the control strategies that were proposed in the report and on the basis of that review, it was concluded that “...it is feasible for the control modes to be implemented, but detailed design would need to be undertaken, and controller software modification would be necessary” (Cory Ross, ITS Technology Manager, Network Operations / ITS Operations, Main Roads, email dated 8 March 22)

Use of automated video analytics on Principal Shared Paths

This research applied some of our ongoing work on video analytics as a proof-of-concept for using video surveys as an alternative to pneumatic tubes to provide insights into how pedestrians and cyclists use PSPs. PATREC was sub-contracted by WSP to do the research as part of a study for Main Roads.

“I am very impressed with the analysis, particularly the manner in which the O-D volumes and speed profiles have been communicated. Please thank your team for me. The heatmaps are very impressive too... I am beginning to understand the huge potential of this technology. I am confident our client MRWA will feel the same way after reading the report” (James Pearse, Associate Transport Engineer/Team Leader, WSP, email dated 22 Dec 22)

“Craig [Wooldridge] and I had a quick discussion about the draft report this morning. Our overall thoughts were extremely positive in regard to the format and content within” (Colin De Costa, Project Development Officer, Main Roads, email dated 2 Feb 22)

3.4.2. Stakeholder satisfaction survey results

An on-line survey, comprising nine questions, was developed using Qualtrics to provide feedback to the Director and Board on the level of satisfaction of PATREC partners with the performance of PATREC on an annual basis. The survey for 2021, conducted in February/March 2022, circulated to over 126 stakeholders directly involved in PATREC research, returned a percentage satisfaction rate of 92.3% (n=31), up 1% on the 2020 score of 90.6%. This is the highest satisfaction rate of the six years in which the survey has been run (Figure 1). University partners had the highest response rate (52%), with 32% government respondents and “other”, 16% (Figure 2). All but two (university) respondents agreed that overall, they are satisfied with PATREC's performance, 84% strongly agreeing and 10% somewhat agreeing. “Strongly agree” dominates replies to questions relating to usefulness of outcomes, value for money, good interactions and extending the knowledge base and networks (Figure 2). As in past surveys, “Somewhat agree” dominates the responses to two questions: understanding each other's needs and bridging the gap between research and policy.

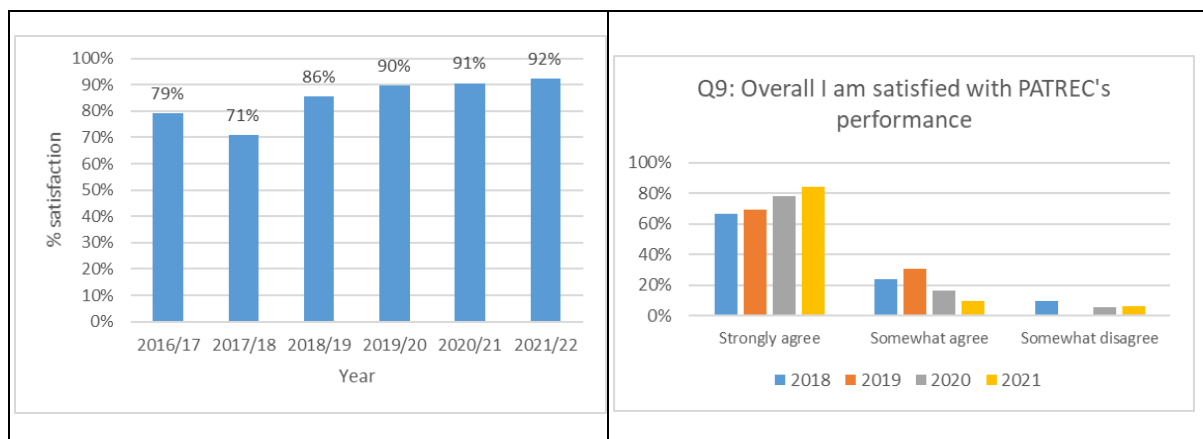


Figure 1: Trend in overall satisfaction with PATREC's performance

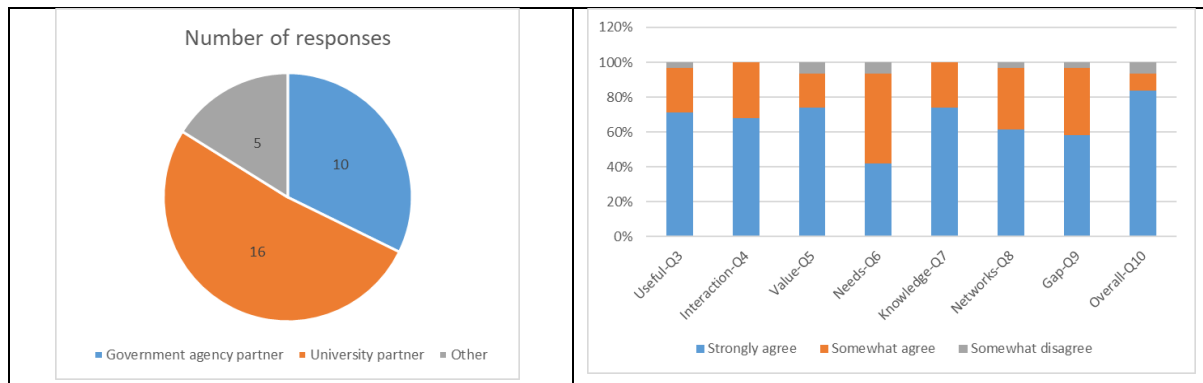


Figure 2: PATREC satisfaction survey response numbers and results (March 2022)

Suggestions provided by respondents:

- More frequent and more updated information on current projects/research outcomes on website (Other)
- Government and industry should invest more in R&D (University)
- Greater clarity about the goals of partners besides PATREC would be helpful, so that reports can be tailored to their needs rather than presenting everything possible, which can be confusing (University)
- PATREC are very visible at both a University and stakeholder level. They are able to bring both groups together to provide answers to complex problems. We have enjoyed our collaboration with them (University)
- More applied research useful to enable innovative mobility trials. Opportunities beyond the current 2 yearly program to undertake research for DoT. Potentially extending the arrangements via iMOVE to engage with other universities as the WfH research has allowed (Government)
- It would be good to have a refresher on PATREC's capabilities - at officer level. This could spark some thinking about potential projects. Do you engage with the Centre for Social Impact? (Government)
- Broaden research focus from roads, freight and modelling. It would be great to see a focus on more policy research, non-motorised transport and land use planning. There should be a strong focus on decarbonising transport and not just on EVs (University)
- Reduce overhead if it's possible. Too much admin burden at the moment (University)
- Very good survey (University)

4. PEOPLE AND RESOURCES

4.1. Staffing

With leadership, administration and coordination by a small PATREC core team, a much wider team of PATREC project research associates from across the partner universities and with some support from adjuncts, consultants and PhD students, are called upon to conduct policy-informing, applied research.

The research team is broadly consistent with that presented in the Strategic Plan with extensions to expiring fixed-term and casual contracts taking place in late 2021 to ensure resourcing is secured to deliver on concluding and commencing core projects and external projects (Table 6). PATREC participants in the new round of PATREC projects (2021-2023) and external projects, have been included in the list (Table 6). Casual contract staff play a vital role in delivering on the research, usually in the role of research assistants, but have not all been included in the list due to the short-term nature of their involvement.

In addition to the PATREC-funded core team, PATREC involves a number of academics who are employed full time by partner universities but who participate on an in-kind basis to conceptualise and manage projects, direct research assistants, undertake research and identify opportunities (Table 6). Limited use is also made of consultants where relevant expertise is not available within the partner universities.

Table 6: PATREC project researchers

Sharon Biermann	Director (0.4 FTE)
Vacant	Centre Administrator – funding re-allocated to research (0.8 FTE)
Sharon Biermann	Director – ongoing, contingent on funding (0.6 FTE)
Yuchao Sun	PATREC Senior Research Fellow (traffic engineering); fixed-term (to Dec 2022) (1.0 FTE)
Sae Chi	PATREC Research Fellow (transport economics); fixed-term (to Dec 2022) (1.0 FTE)
Tristan Reed	PATREC Research Assistant, Curtin (to 18 November 2022) (0.8 FTE)
Konstantinos Sakellariou	PATREC post-doc to support Chao Sun (2-year contract to Dec23) – appointment made, visa arrangement in process (1.0 FTE)
Sergio Matias	PATREC Research Assistant to Chao Sun (computer science); casual contract (to June 2022) (1.0 FTE)
Rachel Cardell-Oliver	Research Associate, UWA Computer Science
Mark Reynolds	Research Associate, UWA Computer Science
Doina Olaru	Research Associate, UWA Business School
Kirsten Martinus	Research Associate, UWA Geography and Planning
Brett Smith	Research Associate, UWA Business School
Julie Lee	Research Associate, UWA Business School
Thomas Stemler	Research Associate, UWA Mathematics
Michael Small	Research Associate, UWA Mathematics and Statistics
Shannon Dee Algar	Research Associate, UWA Forrest Prospect Fellow, Maths and Statistics
Atif Mansoor	Research Associate, UWA Computer Science and Software Engineering
Farid Boussaid	Research Associate, UWA Electrical, Electronic & Computer Engineering
Mohammed Bennamoun	Research Associate, UWA Electrical, Electronic & Computer Engineering
Lynn Meuleners	Research Associate, WA Centre for Road Safety Research, UWA

Gina Trapp	Research Associate, Telethon Kids, UWA
Anna Gannett	Research Assistant and PhD candidate, Population and Global Health, UWA
Paula Hooper	Research Associate, AUDRC, UWA
Julie Saunders	Research Associate, Population and Global Health, UWA
Tele Tan	Research Associate, Electrical Engineering, Computing and Mathematical Sciences, Curtin
Jun Li	Research Associate, Civil and Mechanical Engineering, Curtin
Carey Curtis	Research Associate, Adjunct Prof UWA
Caroline Knight	Research Associate, CTWD, Curtin
Courtney Babb	Research Associate, Urban Planning, Curtin
Sharon Parker	Research Associate, Director, CTWD, Curtin
Cecilia Xia	Research Associate, Spatial Sciences, Curtin
David McMeekin	Research Associate, Electrical Engineering, Computing and Mathematical Sciences, Curtin
Kerry Brown	Research Associate, Employment and Industry, Business and Law ECU
Reza Kaini Mavi	Research Associate, Supply Chain and Project Management, Business and Law, ECU
Ferry Jie	Research Associate, Supply Chain and Logistics Management, Business and Law, ECU
Hadrian Djajadikerta	Research Associate, Strategic Management Accounting, Business and Law, ECU
Zhaoyong Zhang	Research Associate, Finance and Economics, Business and Law, ECU
Mohammad Iranmanesh	Research Associate, Vice-Chancellor's Research Fellow, Business and Law, ECU

4.2. Finances

2021 ended with a closing balance of \$371,511, including the balance brought forward from 2020 of \$106,654. Actual project income slightly exceeded budget (by \$21,702) with total income earned at \$1,612,860 (Table 7). External project income exceeded budget by \$123,476 while core projects lagged behind budget by \$101k due to some delays in core project delivery. Actual expenditure did not reach budgeted expenditure (by \$218k) due largely to lower than expected project expenditure, mainly as a result of long lead times to project commencement.

Table 7: Financial summary for 2021

PATREC Income and Expenditure 2021	YTD Actual 31 Dec 2021	Budget 2021	Variance Budget vs YTD Actual
INCOME			
WA Government Grants (core subscriptions)	285,320	285,320	0
Universities Sponsorship (core subscriptions)	205,838	205,838	0
iMOVE/PATREC core project	198,226	300,000	-101,774
External Research Grants & Contracts	923,476	800,000	123,476
Accrued Interest	0	0	0
Total Income	1,612,860	1,591,158	21,702
EXPENDITURE			
PATREC OFFICE	126,036	135,768	9,732
RESEARCH PROJECTS	1,221,968	1,430,246	208,278
Total Expenditure	1,348,003	1,566,013	218,010
YTD BALANCE	264,857	25,145	239,712
Balance Brought Forward from 2020	106,654	102,688	3,966
CLOSING BALANCE (incl Balance B/F)	371,511	127,832	243,678

5. GOVERNANCE

5.1. Board members

The PATREC Board comprises a senior representative of each of the collaborating parties and a Chair who is independent of all Parties. Reece Waldock continued as the Independent Chair of the Board. Board membership in 2021 remained stable with no change in membership since 2020 (Table 8). The PATREC Director is an ex officio member of the Board. The PRAC Chair and PTA are also invited to Board meetings.

Table 8: PATREC Board members 2021

2021
Adjunct Prof Reece Waldock AM, Independent Chair
Mr David Caddy, Chair, Western Australian Planning Commission
Mr Peter Woronzow, acting Director General Transport, Western Australia
Mr Steve Beyer, Director, Portfolio Strategic Projects Office, Department of Transport
Prof Nathaniel Belcher, Professor of Architecture Head of School, School of Design and the Built Environment, Curtin University
Prof Kerry Brown, Director of the Centre for Innovative Practice, Edith Cowan University
Prof Andrew Page, Pro Vice-Chancellor (Research), The University of Western Australia
Mr Ian Duncan, Executive Manager, Infrastructure, WALGA

5.2. PATREC Research Advisory Committee (PRAC)

Comprising two senior representatives from each partner organisation, chaired by a nominated representative of one of the government partners, elected by the Board, the objectives of PRAC are to:

- introduce an element of formality and rigour to the research project identification, selection, support, monitoring and dissemination process;
- enhance communication amongst partners; and
- advise the Board on project level matters, allowing the Board to focus on strategic matters.

Steve Atkinson (Main Roads) and Damien Martin, continued as Chair and Deputy Chair respectively in 2021 (Table 9). The PRAC meetings are held three times a year, two weeks in advance of Board meetings.

Table 9: PATREC Research Advisory Committee (PRAC) members

Name	Organisation
Steve Atkinson (Chair)	Main Roads WA
Anne-Marie Brits	Department of Transport
Justin McKirdy	Department of Transport
Douglas Morgan	Main Roads WA
Scott Fennelly	Main Roads WA
Damien Martin (Deputy Chair)	Department of Planning, Land & Heritage

John Chortis	Department of Planning, Land & Heritage
Martin White	Public Transport Authority
Tele Tan	Curtin University
Francesca Perugia	Curtin University
Hadrian Djajadikerta	Edith Cowan University
Ferry Jie	Edith Cowan University
Doina Olaru	The University of Western Australia
Brett Smith	The University of Western Australia
Sharon Biermann	PATREC

5.3. Project steering committees

All PATREC core projects are led by steering committees, comprising key researchers as well as government stakeholders and chaired by a government agency representative (Table 10). Steering committees have oversight on progress, provide access to information and data and review and accept key outputs. Steering committees are established in the process of project development and agreement execution and provide significant value in ensuring research is relevant to policy objectives and delivers impact.

Table 10: Core project steering committee participation in 2021

Project title	Government	Research
Transport environment and kids... 15 years on (PATREC-iMOVE)	Chair: Michelle Prior, Liam Heitson, Zarin Salter, David Wake (DOT); Damien Martin (DPLH); Sebastian Davies-Slate (WALGA)	Gina Trapp, Anna Gannett (Telethon kids, UWA)
Identifying opportunities to address transport disadvantage in Perth (PATREC-iMOVE)	Chair: Claire Thompson, Leonie Gibbons (DOT)	Sae Chi (PATREC); Cecilia Xia (Curtin)
Integrated IoT, computer vision and machine learning technologies for smarter bridge health monitoring and prediction (PATREC-iMOVE)	Chair: Raquib Hossain, Steve Atkinson, Jewel Parvin (Main Roads); Sebastian Davies-Slate (WALGA)	Wensu Chen, Jun Li (Curtin); Atif Mansoor (UWA); Chao Sun (PATREC)
A real time model for estimating delays at traffic signals (PATREC-iMOVE)	Chair: Johann Brits, Chris Scholte, Graham Jacoby (Main Roads)	Chao Sun (PATREC)
Machine learning models for road maintenance investment decision making (PATREC-only)	Chair: Qindong Li Lalinda Karunaratne	Chao Sun (PATREC)
Adequacy of the road freight transport network to support the freight task in Australia's North West now and into the future (PATREC-iMOVE)	Chair: Fabrice Gregoire (DOT); Director of HVS (or alternate); Damien Martin (DPLG); Sebastian Davies-Slate (WALGA), Flori Mihai (Main Roads)	Reza Kaini Mavi, Hadrian Djajadikerta (ECU)
Modelling perimeter controls based on macroscopic	Chair: Graham Jacoby Rafael Carvajal Cifuentes Cory Ross (Main Roads)	Chao Sun (PATREC)

fundamental diagrams (PATREC-iMOVE)		
Enhanced vehicle detection at traffic signals and smart freeways (PATREC-iMOVE)	Chair: Cory Ross, Kingsley Pettit (Mairn Roads)	Farid Boussaid, Mohammed Bennemoun (UWA)
Working from home - changes in transport demand – Perth (PATREC-iMOVE)	Chair: Claire Thompson (DoT) Wes Soet (MRWA), Renlong Han (DoT), Damien Martin (DPLH), John Chortis (DPLH)	Sharon Biermann (PATREC); Doina Olaru, Brett Smith, Julie Lee, Kirsten Martinus (UWA); Caroline Knight, Tristan Reed (Curtin); Carey Curtis (PATREC adjunct)

6. PERFORMANCE AGAINST KPIS AND TARGETS

Broad key performance indicators set for PATREC relate directly to the value-add role or purpose for which PATREC was established. The university collaborators require an increase in research profile and performance while the government partners require better evidence on which to base policy and investment and development spending decisions. The number of performance indicators has been reduced to essential academic and policy impact indicators with a focus on outputs and outcomes rather than inputs. Performance to date against 2021 targets as set in the Annual Business Plan 2021, is summarised in Table 11.

Table 11: Key performance indicator targets (2021) and achievements as at 31 December 2021

Performance Indicator	Target 2021	Achieved as at 31 Dec 2021
Academic Performance Indicators		
Number of journal papers published (Table 2)	8	6
Number of peer-reviewed book chapters published	1	0
Number of peer-reviewed conference papers published in proceedings (4X ATRF, 1X FactBase) (Table 2)	0	5
Number of peer-reviewed books published	0	0
Number of post graduate research students attracted, underway and graduated	2	6
Value (\$) of [direct] research funding secured (Table 7)	\$1,100,000	\$1,121,702
Policy Impact Performance Indicators		
Number of high impact, policy-informing projects/sub-projects completed: <ul style="list-style-type: none"> Enhanced land use inputs to strategic transport models through advanced econometrics Modelling perimeter controls based on macroscopic fundamental diagrams Extension to drone video analytics Multi-objective genetic algorithm optimisation for network widening and maintenance scheduling PSP application of video analytics to cyclists and pedestrians 	3	5
Number of substantive Technical Reports/Working Papers accepted/published (Table 2)	3	8
Number of PATREC Perspectives/iMOVE news articles published on PATREC and/or iMOVE websites (Table 2)	3	4
Number of presentations at PATREC and other connection events (Table 4)	10	18
Number of connection events arranged and held: <ul style="list-style-type: none"> WFH seminar Risk Management seminar 2 UWA seminars John Taplin Inaugural Memorial Lecture 	3	5
Number of short courses, unit contributions presented (CUBE Land, Transport Engineering, 2X Transport Geography/Planning)	3	4
Stakeholder satisfaction indicator	85%	92.3%