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NEW KNOWLEDGE APPLICATIONS IN AUSTRALASIAN TRANSPORT

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New Knowledge Applications in Australasian Transport is a digest of recent and current research generating new knowledge and applications of new knowledge which have made our mobility safer, more sustainable and better value for money for taxpayers.

ARRB – YOUR NATIONAL TRANSPORT RESEARCH ORGANISATION

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FOREWORD

I am very proud that the re-birth of the ARRB Journal comes at the time that ARRB celebrates its 60th anniversary. The ARRB Journal had been for many years the principal source of road and infrastructure information for practitioners across the length and breadth of Australia. To ensure that remains the case we have made some significant changes while still pursuing the goal of knowledge sharing amongst planners, designers, builders, operators, and academics.

We have moved the Journal away from a purely academic focus towards being a source of research and implementation-based new knowledge of interest to all practitioners. The articles are designed to give a quick understanding of new opportunities, leaving the reader to choose whether to pursue details on specific aspects. To enable this further enquiry, the traditional paper-based journal has been replaced with a new on-line version accompanied by a portal for video insights into the stories and opportunities for readers to ask questions and seek further information on the topics presented. The topics discussed and articles written will, over the regular publications of the journal, cast light on the issues that ARRB and the transport infrastructure community more generally have been working on.

This new journal format will call on practitioners and researchers from the broader transport and infrastructure community to participate in the flow of new knowledge across Australia and New Zealand and provide insights to those seeking innovative solutions to real world problems.

The ARRB journal will, over the years ahead, become the "go to" source of information and ideas generation across a range of topics that will usher in a new golden age of infrastructure development in Australia and New Zealand, and the associated transport outcomes which it enables. The journal has had a long and proud history that, now re-awakened, will serve our infrastructure community well.

Michael Caltabiano

ARRB Chief Executive Officer

IN THIS ISSUE

When we considered what content to select for the first issue, we wanted to highlight a specific aspect of 21st Century mobility and the knowledge needed to produce the mobility future we deserve. Transport and mobility is a complex and multi-disciplinary field. Instead of selecting a particular aspect of endeavour, we have chosen to select a showcase of the wide variety of activity needed.

In our opinion piece, Dickson Leow and Dr Ronny Kutadinata set out some of the mindset changes needed if we are to take advantage of the technological advances that support integrated mobility.

Two articles focus on the importance of standards and specifications when innovation is essential. In the first, Drs James Grenfell and Mike Shackleton provide an update on ARRB's fast-track progress towards a specification for the use of plastics in bitumen and asphalt. In the second, Danielle Garton and Jaimi Harrison describe the rapid development of a field test method for determining the age of bituminous seals.

COVID-19 is a present reality that will shape our mobility future. John Catchpole and Dr Farhana Naznin describe their analysis of changes in safety outcomes during the various government-imposedCOVID-19 restrictions around the nation.

Ridesharing is an increasingly reality. There is a great deal of hype around what this phenomenon can do for travel patterns in Australia and New Zealand. Dr Elnaz Irannezhad and Associate Professor Renuka Mahadevan unpack some factors which have been shown to influence decision making about sharing rides in Australia.

Mornington Peninsula Shire's work with optimising their peak season parking operations using 'smart city principles' shows that the concept of Smart Cities is not restricted to large capital or regional cities. Dr Robert Kochhan describes how their parking system improvements were evaluated and the degree to which certain performance indicators improved.

The article by Dr Tim Martin and Lith Choummanivong demonstrates the value of long-term commitment to research and development of new knowledge. In describing their development of road deterioration and works effects modelling from Long Term Pavement Performance studies, they provide a case study on how small but regular investments can lead to significant advances on knowledge.

Our final article outlines some work done previously on identifying research or knowledge gaps which should be addressed as a matter of priority. Readers are invited to provide their own views on these priorities to help ensure that the creation of new knowledge is focussed on the areas that need it most.

Mike Shackleton, PhD

Chief Research Officer, ARRB

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ABOUT THE AUTHORS

Dickson Leow is a recognised mobility and technology leader with more than 22 years of experience in ITS / CAV, Regulatory Affairs, Compliance, Certification, Vehicle Engineering & Design, Vehicle Safety and Intellectual Property Law, in both private and government sectors. His focus is facilitating the integration of smart technologies with infrastructure and enhancing the community's understanding of integrated mobility. He leads the Future Transport Systems team at ARRB.

Dr Ronny Kutadinata is a Lecturer in Mechatronics at Deakin University. He specialises in mathematical modelling of physical systems for optimisation, control and automation. His research interests include vehicle and traffic modelling, traffic network control, and transport optimisation. He had worked as a research fellow and as a consultant engineer, working and/or leading several projects both in industry and academia.

Dr James Grenfell is a Principal Professional at ARRB. He is bringing his pavement engineering experience to bear on the need to increase the use of recycled materials in road pavements through science-backed specifications and guidelines. A major, and urgent, part of this work is the investigation he and ARRB are leading into the use of recycled and reclaimed plastic in safe, sustainable future road infrastructure.

Dr Mike Shackleton has 32 years' experience in research and consulting in road infrastructure and transportation matters on three continents. He has a passion for unsealed and low volume roads serving regional and remote communities because of the impact those roads can have on quality of life. His current research interests involve community attitudes to changes in policies and technology and the future of transport, and research governance.

ABOUT THE AUTHORS CONTINUED

Danielle Garton is a Senior Professional Engineer at ARRB in the Future Transport Infrastructure team, with qualifications in Materials Engineering and Chemistry. At ARRB, Danielle is involved in pavement-based research projects, often looking at the various properties and applications of virgin and/or recycled pavement materials through testing, processing and analysing material performance data.

Jaimi Harrison holds a Bachelor of Science (Chemistry) from Monash University. Jaimi joined ARRB as a member of the summer internship program and quickly adapted to ARRB's dynamic research environment. Jaimi's current interest and research focus lies with the use of recycled materials in pavements and road related infrastructure, including glass, plastics and crumb rubber.

John Catchpole is a behavioural scientist whose enduring research interest has been understanding the factors that contribute to crashes, with a particular focus on intentional risk-taking and unintentional risk acceptance by inexperienced drivers. John has led studies of graduated licensing, novice driver safety, older driver safety, pedestrian safety, unlicensed driving, drink driving, high-risk traffic offenders and many other road safety issues. He joined ARRB in 1988.

Dr Farhana Naznin has strong academic qualifications and experience in the Road Safety, Traffic and Transportation field. Since joining ARRB in early 2019, Farhana has been involved in a wide range of studies including understanding the safety issues related to novice drivers and high-risk traffic offenders, investigating light-vehicle towing crashes, analysing and modelling of traffic data.

Dr Elnaz (Elli) Irannezhad is a Principal Professional at ARRB. She has over 15 years of experience in transportation engineering and planning. Her research interests include modelling of behavioural choice, as well as optimisation and disruptive technologies such as on-demand sharing economy platforms, Logistics 4.0 and blockchain technology. She has published one book chapter and 34 papers in journals and conference proceedings.

Associate Professor **Renuka Mahadevan** (University of Queensland) is an applied economist and an Asia Pacific expert who undertakes empirical evidence-based analysis using data on a wide range of areas from trade, energy and development to well-being and the digital economy. She has written 5 books and published more than 100 scholarly papers. She has consulted for the EU, UN for Women Organisation and the Asia Pacific Productivity Organisation.

Dr Robert Kochhan is an economist at ARRB with a passion for sustainable future transportation and electric vehicles. He has several years of experience in Australia and overseas working on range of electric vehicle topics considering technical specifications, environmental impact, costs and user behaviour. He has also been involved in the design and development of solar-electric vehicles for an Australia solar car team and participated in the Australian World Solar Challenge.

Dr Tim Martin is Discipline Lead: Performance Modelling at ARRB. Tim designed and implemented a major observational study using long-term pavement performance (LTPP) sites and experimental studies with accelerated loading facility (ALF), resulting in the development of pavement deterioration and works effects models for arterial roads. Other research has involved estimating levels of service and the basis for estimating the marginal cost of road wear.

Lith Choummanivong has over 20 years of research experience in pavement-related areas including pavement construction quality management, material characterisation, pavement trials with accelerated load testing and asset management. Over the last 15 years, he has been involved in several long-term pavement studies including sealed and unsealed local roads deterioration modelling, long-term pavement performance (LTPP) and the effects of maintenance on long-term performance of pavement (LTPPM).

MOBILITY FUTURES – CHANGES WE MUST MAKE

A great deal has been written about 'the future' when it comes to a number of things, but particularly so with transport, or its 'mobility' embodiment. What is not always apparent is (a) how rapidly change will take place and (b) how profound change could or needs to be to realise the full potential of the opportunity.

AUTHORS

Dickson Leow

Dr Ronny Kutadinata

KEY DRIVERS OF CHANGE

Manhattan depicts an interesting picture on the development of road operation in the past decade. The horses and carriages were still the main choice of transport in 1900, before automobile almost completely took over in just 18 years. Since then, automobile has been the most dominant mode of road transport changes that may occur to the initial composition.

Figure 1: A look on the road in Manhattan throughout the past **decade**

1903 1918 2018

Beijing interestingly underwent a similar change to Manhattan (or the western world), yet the change occurred more rapidly within the past 40 years.

Figure 2: A similar transformation of roads in Beijing

1900 1979 2019

However, a striking observation is that road operations are essentially identical despite the introduction of automobile. Extrapolating the development of Connected, Autonomous Vehicles (CAVs) in recent years, it is likely that a drastic change on how the roads would look and be operated is imminent. With some vehicle manufactures (OEMs) already predicting deployment in 2030 or earlier, it is imperative that Australia disrupts its transport to accelerate realising the benefits that CAV has to offer.

TIME TO CATCH UP WITH TECHNOLOGY

TECHNOLOGY IS NOT A BARRIER?

It is said connected automated vehicles are already here and will continue to improve with its automation and connectivity within the next 20 years towards full automation. The following pictogram illustrates the levels of automation and likely timing for adoption of each.

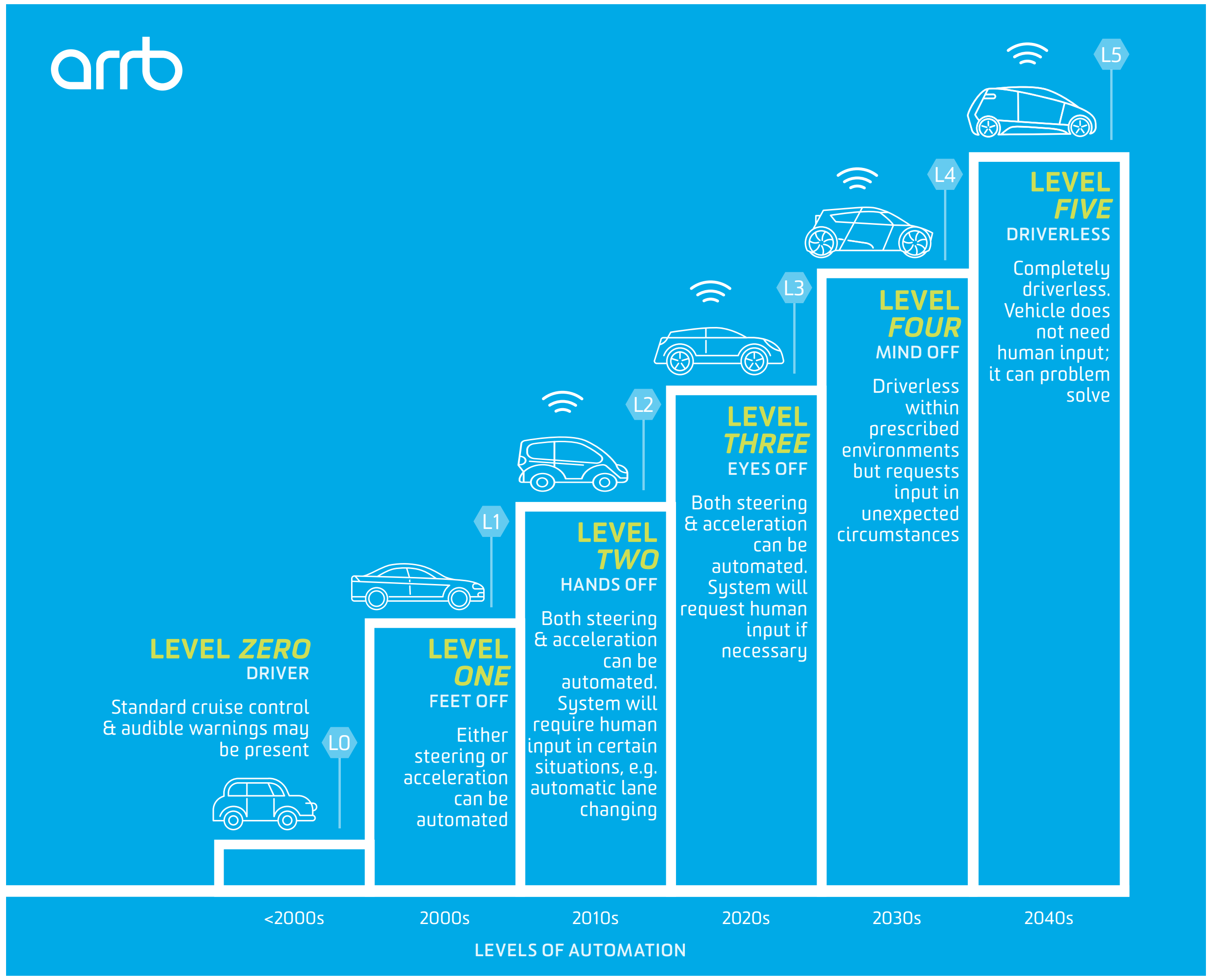


Figure 3: Estimate on timing for adoption of various SAE level of automation

However, it is not the technology, but the psychology associated with 'driverless' or 'automated' vehicles which currently is a significant barrier

FUNDAMENTAL CHANGE OF MINDSETS

The public in general are still wary and sceptical of the technology. A recent survey coordinated by ADVI (2017) suggests only 25% of the respondents would use a fully automated vehicle. To improve access to social & economic opportunities for mobility, trust in the technology is critical.

A recent audit of the technology transport trials landscape in Australia suggests two key learnings.

- The public are generally not aware of the different technologies available nor the productivity or efficiencies gain.
- They are sceptical of the security, reliability, and trustworthiness of the technology.

It is also predicted that the realisation of the car-sharing model as it applies to automated vehicles in Australia will be challenged by the public. Thus, there are still some significant efforts required to shape the mindset of the public to accommodate a fully shared transport model.

PROMISE OF A BETTER TRANSPORT FUTURE

CAV has been heralded as a means of drastically reducing on-road crashes. It was initially predicted that CAV will eliminate all human-error related crashes. (LawInfo,2017). Despite being unreasonably optimistic that rough estimate gives confidence that CAV will improve road safety and, ultimately, reduce the number of fatalities and injuries on the road.

In recent years, many experts have started to form a view that realising the safety benefits of AV may prove to be a challenge, mainly due to the complexity of the operating environment in the current situation; road users' disobedience, different driving behaviours of human drivers, and the sheer number of driving situations that will be encountered by the AV.

The benefits of active safety feature, such as Lane Keep Assist and Adaptive Cruise Control, are very pronounced due to that fact that the drivers are still "in the loop" when it comes to vehicle control and the driving task. When the drivers are disengaged from the driving task (at higher levels of driver assist and automation), their reaction time to take back control in case of fallback request from the vehicle extends significantly (Li et al, 2019). Thus, operation of AV at SAE Level 2 and/or 3, which still relies on the drivers as fallback, could be counterproductive to safety.

Beyond the need for greater trust in AV to realise benefits, there is also the need for a new operational paradigm.

A NEW OPERATIONAL PARADIGM

CAV offers the potential to operate roads more efficiently, such as:

- Close-gap platooning will be able to increase the road capacity in addition to already-proven fuel saving benefit.
- A complex intersection management strategy can be deployed in a 100% driverless traffic environment, reducing travel delay of up to 40%.
- A more uniformly spread traffic / route assignment (both spatially and temporally), which may help reduce network-wide congestion, can be more easily implemented with the help of fully automated vehicles.

The concept of ride-sharing or Mobility as a Service (MaaS) maybe expanded to incorporate driverless vehicles, thus, the vehicle is better utilised compared to the current operational model, where a typical private vehicle may be unused 96.5% of the time-shared CAV operation model may reduce the number of vehicle up to 90% in a city centre environment.

There are already several schools of thought on how to redesign street layout to facilitate the use of automated vehicle to increase road capacity. NACTO (2017) proposes a higher capacity road operation concept that relies on mass transit coupled with CAV operations for a more controlled environment to provide safety for pedestrians traffic (Figure 4).

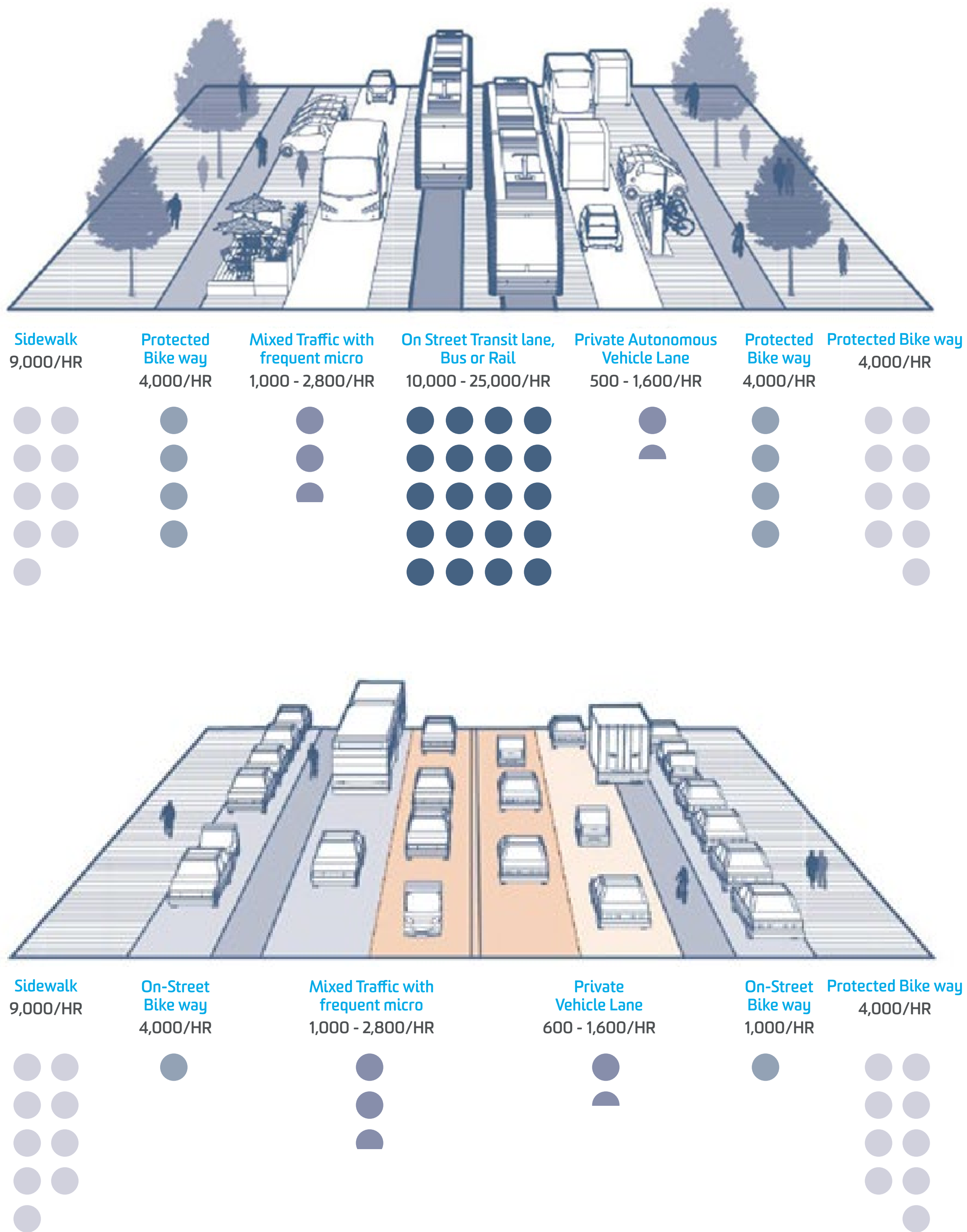


Figure 4: A street redesign concept that emphasises on mass transit coupled with CAV for a more controlled environment (NACTO 2017)

This drastic change in road operation is theoretically achievable right now without requiring much infrastructure investment. Such a radical change requires a careful planning and a holistic approach. Australia lacks a national roadmap that outlines a holistic strategy in facing the advent of CAV. Additionally, each state and territory is often working and running trials independently without a substantial effort to collaborate.

Therefore, Australia needs a paradigm shift into a more national and holistic mindset to be able to improve Australia readiness for CAV deployments and mobility alternatives.

OTHER NECESSARY PARADIGM CHANGES

Whether we, the public, like it or not, we are in transition to fully automated driving. It might be some years away, decades even, but the disruption will change how we interface with each other on the road, be it; vehicle to infrastructure (V2I), vehicle to vulnerable road users (VRU) and/or vehicle to vehicle (V2V).

To manage these disruptions, the following two key aspects are necessary to prevent another "surprised (unforeseen) disruptor" and ensuring that the advancement of technologies serve the good of the public:

- A user-centric and mobility focus
- A holistic approach

User centric and mobility focus

The aim of transport services is to move people from one activity location to another. The more traditional approach is to tackle specific cases of improvements, such as improved traffic corridor management, better intersection control, on-road public transport prioritisation strategy and scheduling optimisation. However, this creates some gaps in a sense that these transport services, although performing well, sometimes do not seem to integrate with each other and thus collectively introduce inconvenience to users.

The future transport would need to focus on serving the needs of the user. The key learning from the recent popularity of various shared economy business models (such as Uber) is that, despite the disruption they bring, these new models better serve the needs of the users, in terms of better access to opportunities and typically at more affordable costs. In transport, this means an improvement on the accessibility of opportunities and places that users are trying to reach.

In recent years, the transport community has focussed on integration, creating a seamless, multi-modal mobility service. The increasing trend in MaaS demonstrated the importance of this seamlessness in servicing people's journeys. The concept of mobility breaks the boundaries of the traditional transport business, which was often siloed (as illustrated in the "Physical Infrastructure" diagram in Figure 5 below). The rapid development in the IT field has disrupted this siloed approach and provided a more "horizontal" perspective (as illustrated in "Digital Infrastructure"). In order to provide the integration, there is a need for an overarching "Logical" and "Conceptual" architecture to ensure a holistic approach.

In order to achieve this integration, better planning and coordination will be required. It was stated that "a carefully planned and managed system can reduce the total number of private vehicles drastically, as well as reducing the distance they travel by 22%, and CO2 emissions by 27%" (Future of Transport, 2018). The planning needs to consider the advancement of technology as discussed above:

- How do we integrate AV to fully realise its potential benefits?
- How do we future proof the transport systems from technology and digital disruptions?

Necessity of a roadmap for a holistic approach

A plan inherently requires the identification an end point which we want to achieve. Many have proposed end-goals for the future transport, with various idealistic visions and/or hypothetical scenarios of the future being conceptualised. However, what usually missing is the roadmap describing how we could achieve these end goals.

For the roadmap to be useful, it needs to identify milestones and provide a realistic plan to achieve the end goal.

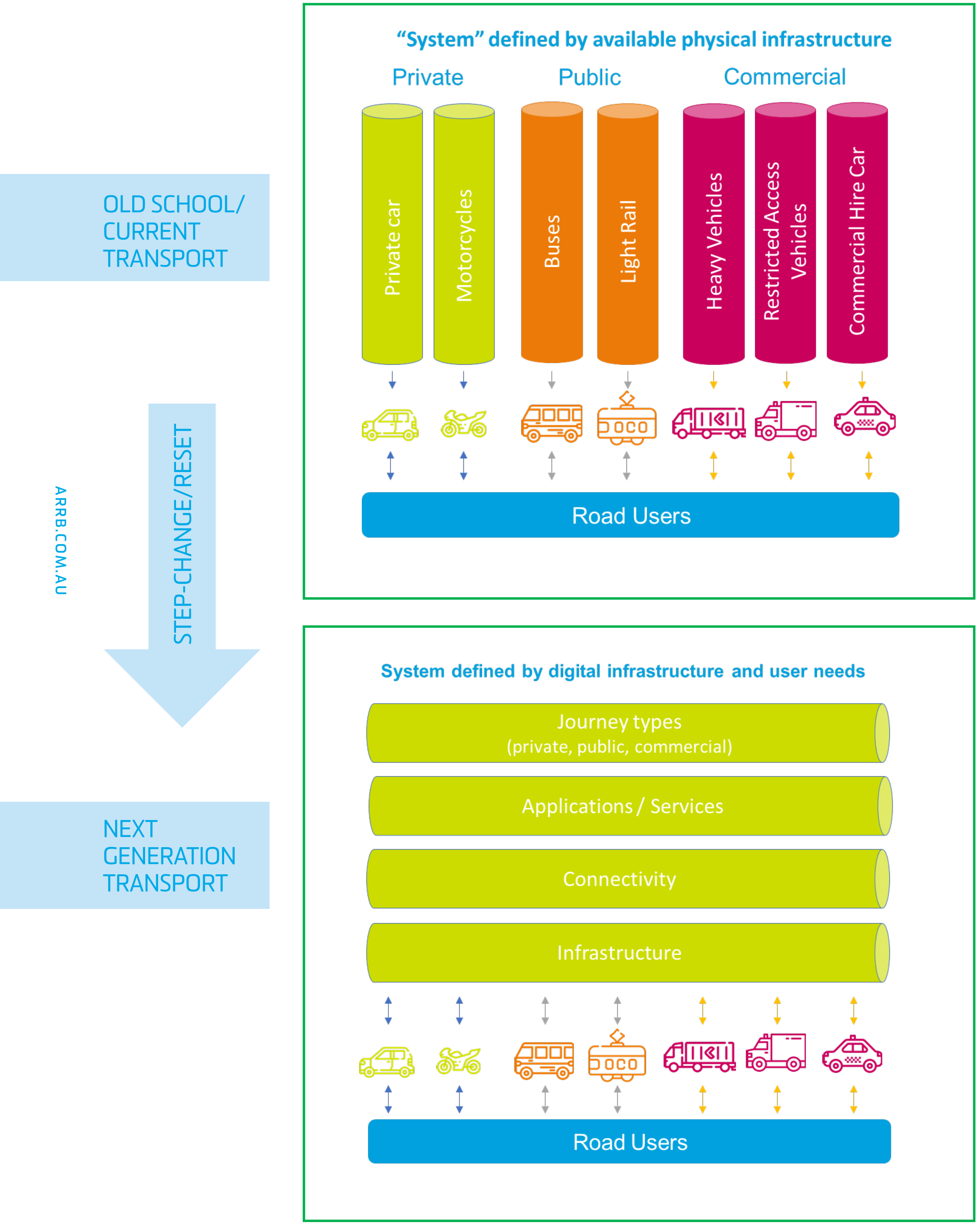
With a clear plan and direction, OEMs and technology suppliers would be more attracted to invest in Australia, since they will be more confident that they will get some form of support from regulators. OEMs if so engaged, would as a group provide a realistic timeline to implement the roadmap.

With city-specific goals in a clear plan, mobility can be designed or facilitated in a way that improves citizen health, provides better education options, and creates the best opportunities for business development and liveability in general

Finally, a clear goal and plan enables the government to better educate and inform the public. This will increase their confidence and acceptance of new technologies, and in so doing, bring the public along the journey of our transport transformation.

Figure 5: Hierarchy of future mobility management

Source: ARRB



CONCLUDING REMARK

Mobility of the future has already arrived. It is inevitable now that connected and automated vehicles (CAV) are fast becoming a reality. It is known that technology will certainly play a critical role in future smart cities, but it should not be the focus. The smart cities of the future are ones which are integrated into the lives of all people, and which anticipate and ensure a safe environment.

The concept of smart mobility is already within our grasp. The next step is to have a holistic approach to mobility – shared responsibility by the government, suppliers and the people. Service-related investments and their establishment needs to be considered just as policies and regulatory standards (if any) for services to operate within the jurisdiction. The traditional thinking of building, operating and managing transportation needs to change. The future transportation system needs to be a holistic system and not a cluster of separate partially-integrated systems.

Australia has a big challenge to reset its transport paradigm. This is not an impossible task, especially since Australia already has the relevant expertise across different jurisdictions and organisations in the transport sector; imagination and redirection of thinking are needed.

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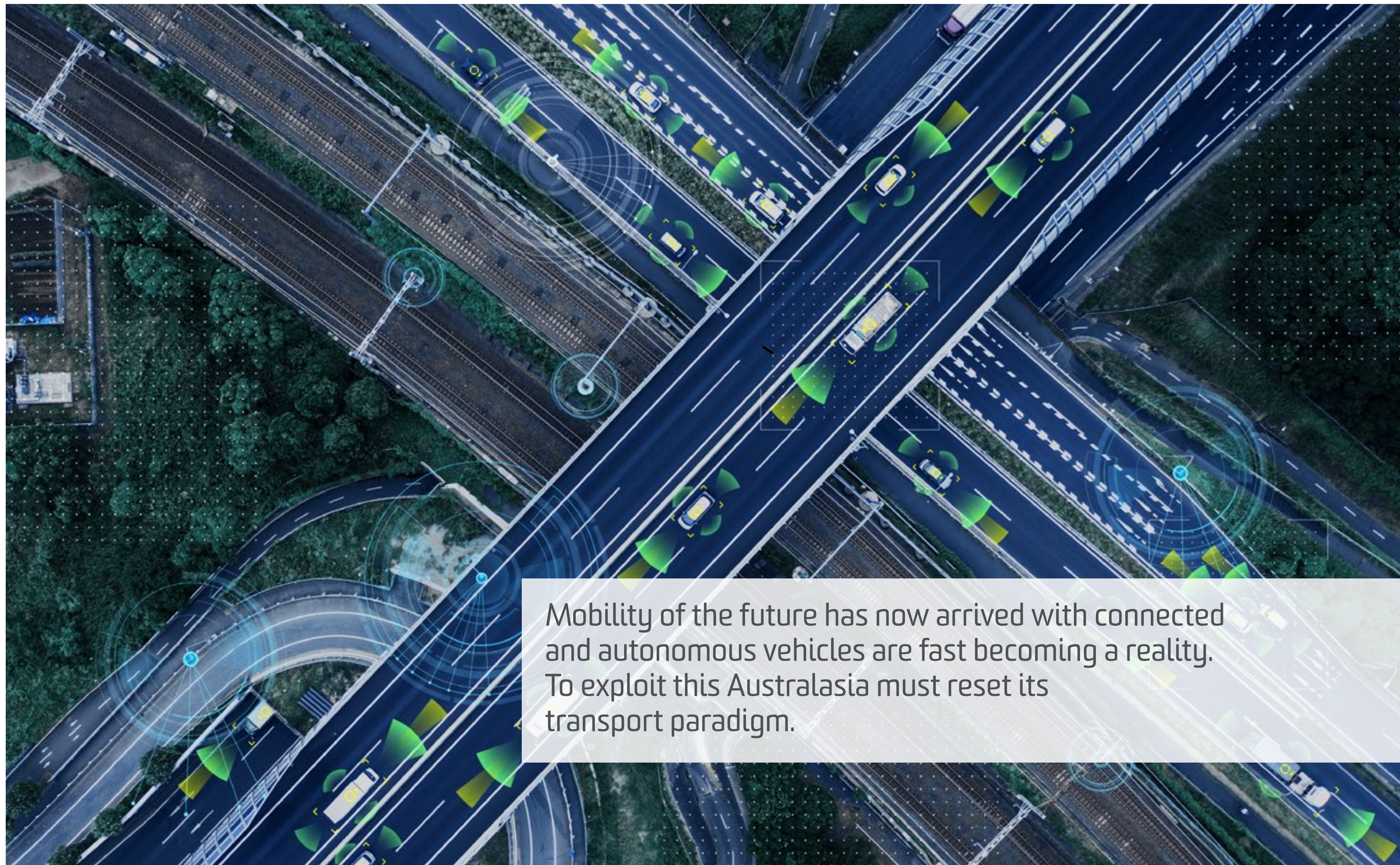

RESEARCH AND DEVELOPMENT (R&D) UPDATE – PLASTICS IN PAVEMENTS

Other than in the medical field, the phrases “research and development” and “race against the clock” are not often used together. However, Australia is facing a crisis in terms of the 3.5 million tons of plastic we use every year, and the need to find domestic means of using it following a looming ban on exporting Australian waste.

Australia’s elected officials have directed that this problem be solved quickly, as it needs to be, and have provided some resources for long-term resolution. Governments and Industry have both been mobilised to find ways in which waste products can be used as valuable assets.

The use of plastics in roads is one such initiative. To date, several providers have demonstrated that plastic can be used in constructing an asphalt road surface. There is a lack of clear evidence of safety, value for money and recyclability of these demonstration products. The pathway to deliver security around the use of recycled plastics in roads rests on the development of clear well researched and performance-based specifications for each State agency to adopt. Without specifications, uptake will be very limited and an opportunity to use even a small slice of the plastic waste stream will be lost.

This short research update provides an overview of work that ARRB is conducting with the aim of producing a specification by early 2021. Ordinarily development of a specification would take a matter of years, but in this case the need is so urgent that it will be done inside of 12 months

AUTHORS

Dr James Grenfell

Dr Mike Shackleton

THE BIGGER PICTURE DRIVING URGENCY

The road infrastructure industry has been practicing circular economy principles for more than 50 years. When a pavement is ‘broken’ we don’t throw it away, we reuse and recycle the materials, often with a small additive of new materials. In answer to the question of whether a particular recycled material can be used in a pavement, the answer is always the same: Yes, provided that it

(i) is safe for people and the environment

(ii) offers value for money for the taxpayer and

(iii) allows the future recycling of the materials with which it is mixed.

When the issue of plastic waste and recycling and reusing it came to the fore, ARRB’s response has been as above – it can be used, provided that specifications exist to ensure the three provisos mentioned above are met.

Australia’s Transport Infrastructure Council members (the Federal, State and Territory Ministers of Transport and Infrastructure) have been keenly encouraging road agencies to determine the extent to which recycled plastics could be used in Australian pavements and have an answer by March 2021. To be able to comply with this unheard-of deadline for a specification, Queensland’s Department of Transport and Main Roads and Main Roads WA engaged ARRB to find the answers by the Ministerial deadline.

ARRB has completed a large portion of this work, and is conducting some pilot testing of plastic/bitumen mixes at our state-of-the-art laboratory facilities in the National Transport Research Centre at Port Melbourne.

A NOTE ON SPECIFICATIONS AND THEIR ROLE IN INNOVATION

Specifications must be living documents, particularly where they pertain to innovations in their infancy. As innovative materials are used, the industry learns more and is then in a position to update specifications. Specifications have two main purposes; (a) to outline what works and how to best get it to work (b) to outline what has been shown to not work and proscribe its use.

Specifications embody the scientific evidence – that which is available at the time - of what passes tests (i) to (iii) above in a form that allows practitioners to use or decline to use an innovation – such as a particular type of plastic used in a particular way. In this way, the use of innovative materials becomes more attractive, through better knowledge and better management of the risks associated with them.

By making the decision on whether an innovation is safe, recyclable and offers value for money an easy one for practitioners, a specification frees the practitioner's scarce time to focus on the best option of any presented.

WORK STATE-OF-PLAY

Initial stages of the project were aimed at assessing the scientific viability of recycled plastics as an additive to bitumens and asphalts. Several demonstration projects had shown that road surfaces could be constructed incorporating recycled plastics. Because of proprietary interests, there was inadequate information available on the materials used, their chemical and engineering properties, their safety (because of an absences of directly applicable standards). Information on likely long-term performance (value-for-money) was not available.

ARRB's first tasks were therefore to do desk-top studies of the three 'provisos' mentioned above, with particular focus on the safety – for both humans and environment aspects. While QTMR and MRWA consider these, ARRB has conducted some pilot work on:

- Chemical characterisation of the most viable waste streams of recycled plastics in concert with some of Australia's leading universities with advanced chemical characterisation capabilities
- Stability of mixtures of bituminous materials and recycled plastics

THE TECHNICAL CHALLENGES AHEAD

The technical challenges that lie ahead are significant and ARRB has mobilised significant part of our national pavements and materials team in order to allow QTMR and MRWA to have answers for their respective Ministers and for TIC early in 2021. The three major technical challenges they are applying their minds to at present are:

- Finding means of stabilising bitumen modified by the addition of plastics. Our very early work in this area on a number of plastics shows that these mixes are unstable and prone to separating out to an unacceptable degree, particularly in storage. The propensity to breakdown varies with the source of plastic and with the percentage of plastic used. The teams are starting to get an understanding of these relationships. There are a number of strategies to pursue in addressing this problem, and the teams are looking into the feasibility of each of these.

- To produce a waste plastic modified asphalt with performance enhancements will require the plastic to interact with the bitumen. There is the possibility to add plastic directly in with the asphalt mix to try to get this interaction, but there are questions about whether the interaction is long enough in an asphalt plant. The best approach is likely to lie with modifying the bitumen directly – but has compatibility and storage stability issues. Waste plastic can be added via a dry process, which incorporates higher melting point plastics as a partial fine aggregate replacement. However, this is likely to be at the detriment of the resultant asphalt properties as the waste plastic will not have as good properties as the aggregate it is replacing.
- As the vast majority of the sealed road network has a seal surface, not asphalt, investigations aimed at optimising the use of plastic must solve the stability of bitumen plastics mix.
- Developing a reliable, repeatable and realistic test to determine the long-term stability of the plastic itself when used in bitumen or asphalts. Microplastics and leaching are significant environmental hazards, and at present 'plastic' roads are being laid without knowledge of their likely breakdown over the duration of their lifecycle.

  We have used our international and university networks to find relevant tests in other fields that can be used as 'proxy' tests in a modern pavement research laboratory.
- Establishing a means of assessing the safety of the material for humans working with it during construction and maintenance.

CONCLUDING REMARKS

This project and the Ministerial deadlines driving it have shown that a lot can be achieved in terms of bringing science and rigour to a new field through developing specifications in a short space of time. It is a model to be encouraged as we grapple with the need to innovate and overcome traditional obstacles to innovation. The faster we can apply some science to hitherto haphazard innovations and reassure the custodians of our infrastructure that they too offer value for money, the faster the taxpayer and the environment will benefit.

ACKNOWLEDGMENTS

The support of QTMR and MRWA in funding this R&D is acknowledged, as is the support of senior executives in those agencies who have spent considerable time in helping accelerate the program.

The authors of this update would also like to acknowledge the highly intensive effort that a large portion of our staff, led by Dr James Grenfell, have made over the last few months and will be making up until publication of the specification in the first half of 2021.

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Plastics are just the latest recycled material to be considered for inclusion in pavements.

They, like all others before them, must be proven to

(i) be safe for people and the environment

(ii) offer value-for-money for taxpayers

(iii) be recyclable themselves when incorporated into pavements

FAST-TRACK DEVELOPMENT OF A FIELD TEST METHOD FOR DETERMINING THE AGE OF BITUMINOUS BINDERS

ACKNOWLEDGMENTS

This project could not have been completed in the time frame it was completed without the selfless assistance of local governments and road agencies who collected and shipped seal samples. We would like to acknowledge (in no particular order):

- Murrindindi Shire Council
- Snowy Monaro Regional Council
- Yorke Peninsula Council
- Dorset Council (Tas)
- Shire of Bruce Rock
- Narrandera Shire Council
- Golden Plains Shire Council
- Shire of Cranbrook
- District Council of Coober Pedy
- Access Canberra
- NACOE
- Northern Territory Department of Infrastructure, Planning and Logistics

Financial support for the study from the Department of Infrastructure, Transport, Cities and Regional Development (DITCRD), as it was then known, is acknowledged and appreciated.

This paper is a much-condensed version of project reports originally written by our project team. The following therefore also had a significant hand in the information behind this article:

- Dr Khulood Hwayyis
- Shannon Malone
- Lydia Thomas

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INTRODUCTION

THE NEED AND APPROACH

A key factor in the performance of bituminous seals, prior to needing maintenance or replacement, is the aging characteristics of the seal itself. The ability to assess the age of in situ binders through a swift and simple technique is therefore advantageous in supporting maintenance and rehabilitation strategies across Australia's sealed road network.

Good-quality asset management records of previous construction or maintenance occurrences are not always available, and therefore budgeting and planning of future works optimally is a challenge for road agencies and local government. It is crucial that appropriate maintenance and rehabilitation programs are supported, with the correct tools and methodologies, to ensure serious failures of roads or erratic reallocation of resources does not occur.

The binders used in a pavement surfacing are subjected to various environmental factors, such as oxygen, UV light, high temperatures and rain; all can contribute to the deterioration of the binder. To assist in the provision of an easy and rapid in situ test to assess the deterioration (or aging) of binders, the Department of Infrastructure, Transport, Cities and Regional Development (DITCRD) sponsored a project to assess the suitability of a portable Fourier Transform Infrared Spectroscopy (FTIR) device as a possible candidate for adoption in practice. Figure 1 shows the device.

Figure 1: Portable FTIR device

FTIR devices are often used to characterise the chemical composition of bituminous samples for comparison against other samples, and the monitoring of any changes that may occur to the initial composition. For this project, the characterisation of binder samples was undertaken using the portable FTIR device to determine the variation in chemical composition due to oxidation (i.e. aging), between samples of different ages, from various climatic regions across Australia.

This paper does not describe the Test Method itself, but rather the general approach to its development as a means of demonstrating that with the right team, development of test methods can take weeks or months rather than the years they normally do.

TEST METHODS IN A MODERN WORLD

Test method development has traditionally been a lengthy process, with the duration normally ascribed to the need for rigour and validation through several studies to ensure the method when released is reliable.

ARRB and the Department of Infrastructure, Transport, Cities and Regional Development (DITCRD) recognised that while a traditional approach was followed, hundreds of millions of dollars would be lost to the economy. ARRB therefore undertook to develop a test method as fast as scientific rigour would allow, on the basis that having something to hand sooner (that might change with use) was better than having a gold-plated method available later.

It is an approach that ARRB is currently using to develop specifications for the use of typical Australian recycled plastics in Australian bituminous products, too.

METHODOLOGY

TECHNICAL BASIS

The modelling of the binder oxidation-to-seal age relationship was the focus of the experimental design in this project. As binders are exposed to environmental factors over time, they begin to experience aging via oxidation. This oxidation of the binder is identifiable in the FTIR spectrum, using the carbonyl peak that occurs at a wavenumber of approximately 1,700 cm-1. The more oxidised a binder is, the larger this peak will be. It therefore makes it possible to correlate the age (in years) of a binder to the area beneath this peak. A typical FTIR spectrum is shown in Figure 2.

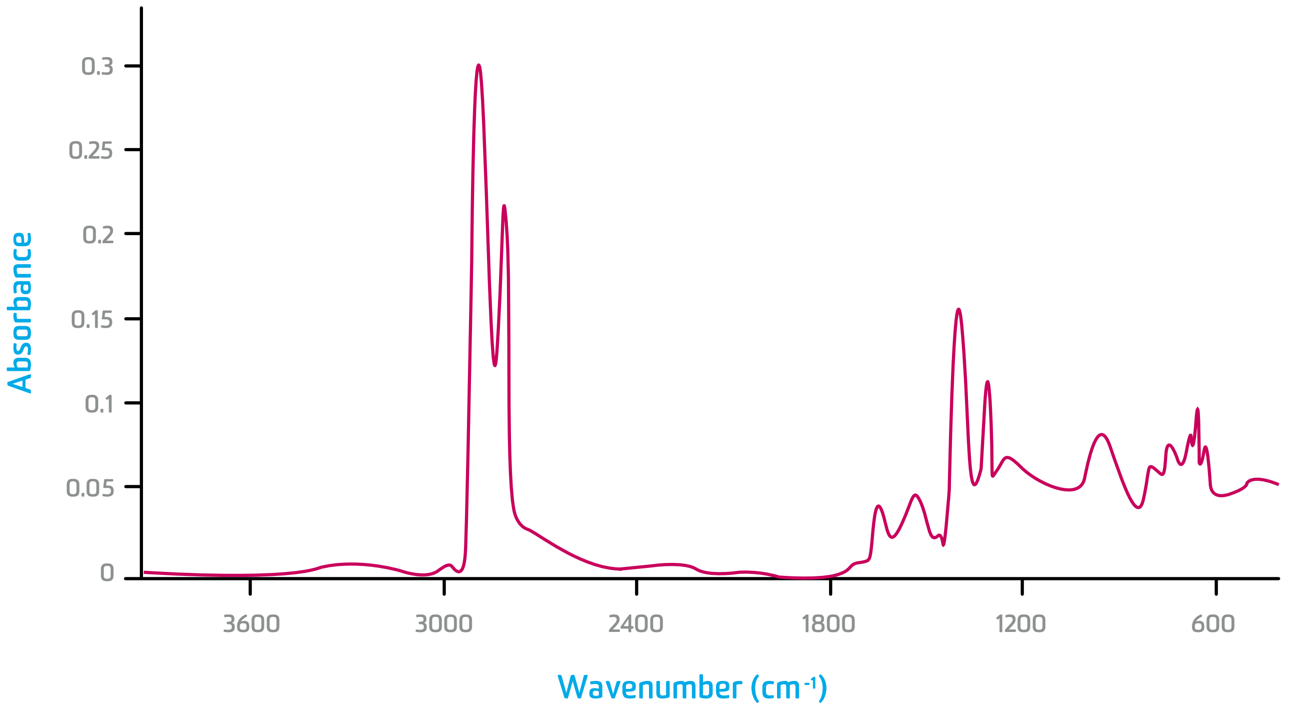

Figure 2 Typical FTIR spectrum for C170 bitumen

For this project, samples of known ages were collected from across Australia and their level of oxidation was analysed using the FTIR pictured back in figure 1. This device is portable and allows for quick, field analysis of samples, and has limited, if any, laboratory-condition requirements for operation. The development and validation of the testing methodology and subsequent results were conducted in the laboratory, however the testing procedure was conducted to mimic that expected in the field. The results were then validated using alternative laboratory testing (e.g. viscosity and stress ratio assessment using the Dynamic Shear Rheometer (DSR)).

Received samples were accompanied by information from the suppliers, including the seal age. In some cases, the ages were noted by the supplier as "best estimates", whilst in others it was determined that the provided age was inaccurate. To help inform whether the provided/estimated ages were reliable or not, other laboratory processes for binder age determination were used, such as the DSR, and visual/tactile physical assessment (e.g. noting how brittle or soft the binder was).

The results obtained from the FTIR testing were used to develop reference curves relating binder age to carbonyl peak area for each sample provider (covering various climatic regions). Using this information, the age of unknown samples could be calculated.

SAMPLE COLLECTION

Samples were collected from multiple climatic regions across Australia so that reference curves applicable to the different regions could be developed.

To assess the relationship between carbonyl peak area and age, samples were collected for three-to-four age groups from 14 regions across Australia.

Seal samples were provided as either core samples or A4-sized slabs, covering the following age brackets:

a. Fresh binder (up to three years old)

b. Intermediate I (between three to ten years old)

c. Intermediate II (between ten to 15 years old)

d. End of life (15+ years old).

For a robust reference curve to be developed, at least three values from three different age groups that have the same type of binder and location were required.

For validation testing using the aforementioned alternative laboratory methods (i.e. DSR), binder was extracted from the samples as per Austroads Test Method AGPT/T191-15.

INSTRUMENT CALIBRATION

As a new portable FTIR device was to be used for most of the sample analysis, the results were compared to a previously commissioned countertop (laboratory based) FTIR device on reference samples to determine if a calibration factor was required. The outcomes of this demonstrated that no calibration factor is required for the portable device.

REFERENCE CURVE DEVELOPMENT

For each climatic region, three samples from at least three age groups were required. If, for some locations, insufficient samples were available, a reference curve was not developed. Different curves were developed depending on the samples and the information provided, including:

a. different binder types:

- i. modified (PMB)
- ii. unmodified (C170)

b. sample locations:

- **a.** WP – within wheelpath (some samples are then separated as inner WP (right), or outer WP (left))
- **b.** OWP – outside of/not within either wheelpath
- **c.** All – combination of inside and outside the wheelpath.

The IR software was used to normalise the outputs, calculate the carbonyl area and develop the reference curves. Excel and SPSS software were then used to develop the models and test the correlation of the reference curves to ensure the IR software results were reliable.

Figure 3 shows four examples of the developed reference curves.

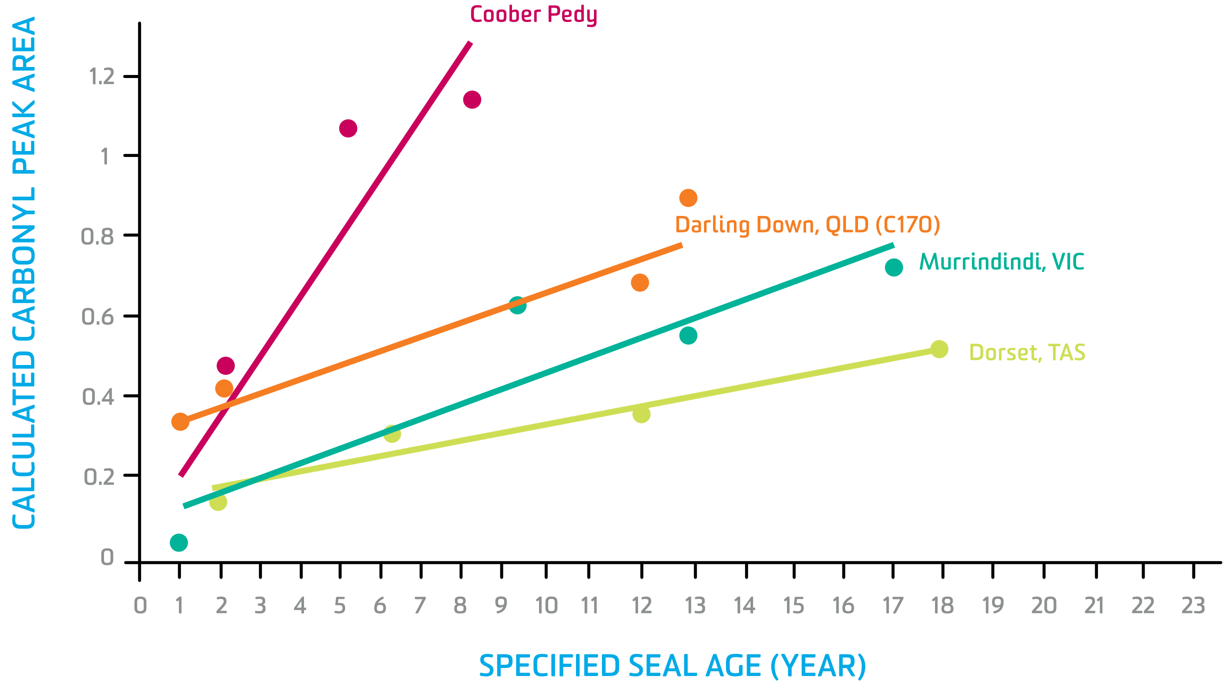

Figure 3 Relationship between specified age and carbonyl peak area for selected regions

OBSERVATIONS ON RESULTS

TECHNICAL BASIS

Upon completion of the laboratory testing and sample analysis, some overall trends were identified and explored for the sample binders.

For all regions, the oxidation was minimal within the first year, and then increased significantly at the early stage of ageing, between four to six years. Beyond this time, oxidation continued to occur, but the rate gradually slowed.

In general, the reference curves demonstrate that regions with higher average temperatures show greater levels of absorbance at the carbonyl peak than those with low average temperatures; this demonstrates the greater impact of higher temperatures on ageing characteristics.

For most participating regions in this project, the IR system software successfully developed relationships linking FTIR absorbance values (area under the carbonyl peak) to the ages of the binder samples. Binder type and sample location were taken into consideration, as different binder types and different locations (relative to the wheelpath) were found to exhibit different ageing characteristics and needed to be evaluated separately.

\For all regions, bar one, the R^2 values indicate that the relationships developed using this methodology appropriately describe the data.

For the local government regions that participated, the reference curve models from this work can be used, in conjunction with the portable FTIR assessment device, to indicate the apparent seal ages of other roads in their networks. This will help plan for future budget and maintenance programs as required.

LGAs wishing to develop their own curves to allow for specific environmental factors can take heart from the ease with which the device can be used and with which it is possible to develop site-specific reference curves.

Figure 4 Field sampling of bitumen for in-field FTIR testing

CONCLUSIONS AND RECOMMENDATIONS

The testing methodology and reference curves developed in this project demonstrate the ability to use the portable FTIR system in supporting the asset management of Australia's sealed road network, through quick and simple characterisation of in situ binder age.

It was demonstrated that FTIR testing can be conducted on samples taken directly from the road surface, with the exception of samples that are highly aged (because of excessive hardness). This provides a promising future for this research methodology, indicating that field analysis can be conducted swiftly and simply, providing immediate results. For highly aged samples, the results can be obtained from laboratory extracted binders, extending the process slightly but still demonstrating great possibility.

The reference curves developed for the test method were limited to using those samples that could be collected, tested and analysed in the short time frames that were set for producing the first iteration of the test method. To further improve the accuracy of these reference curves, it would be necessary to obtain a wider sample base for analysis. For long-term, accurate reference curves, recommendations are as follows:

- For the development of new reference curves, a minimum of four samples from each age group in each region should be collected. More samples would improve the accuracy of each reference curve.
- In terms of further research, the selection of the sample collection process should be based on careful consideration of the context and requirements of the project, to ensure that the samples are collected with a suitable foundation of experience and that all required information is collected with rigour. It is also recommended that trained and well-informed operators conduct the sub-sampling (sampling binder from provided seal specimens), testing and reference curve development to ensure improved accuracy.
- Another consideration for even further refinement is the crude bitumen source, to study the variation in the results between samples of the same age within the same climatic region.

In terms of the implementation of this work in the field, it is recommended that an operator with experience, or appropriate training in utilising the FTIR device, carry out the seal sampling and analysis across any given jurisdiction. This will help to identify the age of seals where the date of construction information is not easily accessible, improve the accuracy of obtained results and minimise invested resources.

As the research methodology is applicable to both modified and unmodified binders, for a wide age range, this research model could be also applied to different aspects of the road asset aside from binder age (potentially the determination of type, and quantity of additives or modifiers within the binder), by identifying and studying different peaks within the FTIR spectra.

The appropriate application of this model could help road owners to manage their networks and provide for long-term maintenance plans, select and prioritise road sections for resurfacing and resealing operations, and to budget for the required future work in their networks.

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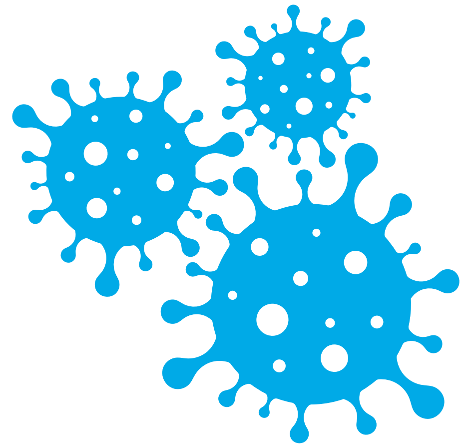
IMPACT OF COVID-19 ON FATAL CRASHES IN AUSTRALIA



INTRODUCTION

2020 has been a year like no other for road travel in Australia. The onset of the COVID-19 pandemic at the start of the year led governments to impose restrictions on the movement of people in all Australian states and territories by March. With people allowed to leave home only for specified essential purposes, it quickly became obvious to the casual observer that vehicular traffic flows were greatly reduced across much of the network, and congestion had all but disappeared. By August, as restrictions were gradually being eased across much of Australia, a second and much larger wave of infections led to the imposition of even tighter restrictions on travel in Victoria.

With vehicular travel greatly reduced, there were hopes for a reduction in crashes, deaths and injuries on the roads. Reduced road travel implies fewer opportunities for road users to be involved in crashes. So was the reduction in motor vehicle use accompanied by a corresponding reduction in road trauma? The Australia and New Zealand Driverless Vehicle Initiative (ADVI) commissioned the Australian Road Research Board (ARRB) to investigate changes in road travel and road trauma during the lockdown period, and the links between them. This article provides a brief account of the findings.

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COVID AND PRE-COVID PERIODS

Australian jurisdictions began to apply restrictions on movement during March 2020, so any impact of the pandemic on traffic volumes and crashes was expected to begin in that month. The investigation was conducted in September 2020, so information about travel and crashes was available only to the end of August 2020 at the latest. The COVID period was therefore defined as the period from March to August 2020.

To allow for the influence of seasonal factors, such as weather and school holidays, it was important that travel and crashes during the COVID period be compared with travel and crashes during the same months of earlier years. The pre-COVID period was therefore defined as the months of March to August in the years 2017 to 2019 when data were available for these years, or the months of March to August 2019 when data were not available for the earlier years.

CHANGES IN ROAD TRAVEL

Ideally, data on driving exposure would be used to convert crash counts to crash rates per unit exposure (crashes per million vehicle-kilometres travelled). However, due to the recency of the COVID period, estimates of driving exposure (such as those generated by the Australian Bureau of Statistics [ABS] Survey of Motor Vehicle Use) were not available. It was therefore necessary to make use of surrogate indicators of vehicular travel, including fuel sales, vehicle detection counts and responses to an online travel survey.

Vehicle detection counts recorded at signalised intersections in SA and Victoria by the SCATS signal control system are not counts of passing vehicles, since each vehicle may have been detected more than once at the same intersection. Nevertheless, changes in the detection counts are indicative of changes in traffic volumes on urban major and minor arterials (where traffic signals are generally located).

NATIONAL PETROL SALES

Australian petroleum sales data were obtained from the Department of Industry, Science, Energy and Resources (2020). The data include sales of regular, premium and ethanol-blended petrol. Diesel sales were excluded because available data did not separate automotive diesel fuel from marine and industrial diesel fuel and biodiesel blends. In any event, 73% of registered vehicles in Australia are fuelled by petrol and only 26% by diesel, with 1% using other fuels (ABS 2020).

Table 1 summarises the decrease in petrol sales during March–July 2020 compared with the same period averaged across 2017–2019. (Data for August 2020 were not yet available.) Nationally, the reduction in petrol sales from March to July 2020 was 21%, with the biggest reductions occurring in Victoria and Tasmania. If data had been available for August 2020, when Stage 4 restrictions applied in Victoria, a larger decrease in petrol sales in Victoria may have been recorded.

State/territory	% Change
NSW + ACT	–22.5%
NT	–2.6%
Qld	–17.4%
SA	–16.6%
Tas	–26.1%
Vic	–26.3%
WA	–16.9%
Australia total	**–21.4%**

Table 1 Change in petrol sales from March–July 2017–2019 to March–July 2020, by state or territory

TRAFFIC COUNTS SUPPLIED BY SA DEPARTMENT FOR INFRASTRUCTURE AND TRANSPORT

At ARRB's request, South Australia's Department for Infrastructure and Transport (DIT) undertook an analysis of SCATS vehicle detection counts from permanent traffic counting stations at signalised intersections in Adelaide and rural South Australia. The Department's analysis concluded that the maximum impact of the pandemic on traffic volumes was seen in early April 2020, when traffic counts were down 30–35% compared with the corresponding period in 2019. By mid-September 2020, traffic volumes had fully recovered to the same level as in 2019.

VICTORIAN SCATS DATA

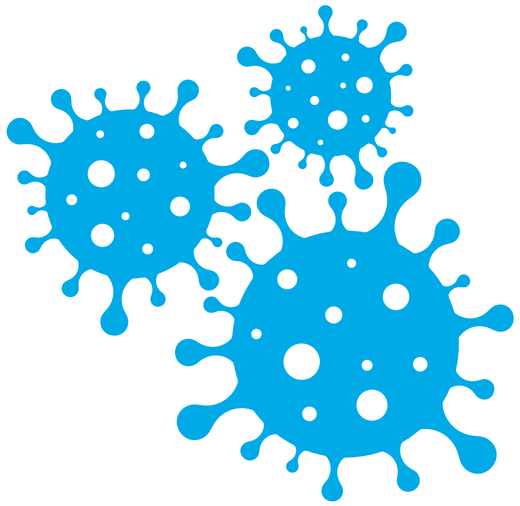
During the COVID period (March–August 2020), vehicle detections recorded by SCATS were reduced by 27% relative to the corresponding period in 2019.

The ABS divides Victoria into Greater Melbourne and the Rest of Victoria, with the majority of signalised intersections being located in Greater Melbourne. The drop in vehicle detections during the COVID period was larger in Greater Melbourne (28%) than in the Rest of Victoria (19%).

UNIVERSITY OF SYDNEY TRAVEL SURVEY

The first wave of a household travel survey by the University of Sydney (Beck & Hensher 2020), conducted in early April at the height of the first wave of COVID-19 around Australia, investigated the number of trips undertaken, rather than the distance travelled. All 1073 respondents were aged 18 or more and three-quarters were from NSW, ACT, Victoria and Queensland.

Respondents reported that the number of trips (all travel modes) made by households per week in early April was 54% lower than in early March (before the major impact of the pandemic). The number of car trips was down 53%. Active transport (walking and cycling) trips were also down in absolute terms but up as a percentage of all trips. Food shopping trips were down less than trips for other purposes, and hence comprised a higher proportion of all trips.



CHANGES IN ROAD TRAUMA

Fatal Crashes in Australia

Data on fatal crashes during the COVID period and earlier years were obtained from the Australian Road Deaths Database, maintained by the Bureau of Infrastructure, Transport and Regional Economics (BITRE 2020). Fatal crashes during the COVID period (March–August 2020) were compared with the same months averaged across the previous three years (2017–2019).

Table 2 shows that the fatal crash count for the whole of Australia was down 10% during the COVID period. Table 3 shows that fatalities across Australia were down 8% for the same period. Two-tailed binomial tests revealed that the decrease in fatal crashes was statistically significant ($p=0.044$), but the decrease in fatalities was not ($p=0.102$). Every jurisdiction recorded decreases except Queensland, where there was an 11% increase in fatal crashes. Fatalities decreased for drivers, motorcycle riders, passengers and pedestrians during the COVID period, but increased for pedal cyclists.

State/territory	Ave. 2017–2019	2020	Change
ACT	2.7	2	–25%
NSW	168.0	136	–19%
NT	17.0	14	–18%
Qld	111.0	123	+11%
SA	48.7	44	–10%
Tas	15.3	13	–15%
Vic	111.7	98	–12%
WA	76.0	66	–13%
Australia total	**550.3**	**496**	**–10%**

Table 2 Change in fatal crash counts during the COVID period by jurisdiction

Road user type	Ave. 2017–2019	2020	Change
Driver	276.7	262	–5%
Passenger	108.7	97	–11%
Pedestrian	86.0	69	–20%
Motorcycle rider	96.7	85	–12%
Pedal cyclist	21.0	27	+29%
Other*	5.0	8	+60%
Total	594.0	548	–8%
WA	76.0	66	–13%
Australia total	**550.3**	**496**	**–10%**

Table 3 Change in fatality count during the COVID period by road user type

* 'Other' includes motorcycle pillion passengers, any other road user types and unknown road user type.

FATAL CRASHES IN QUEENSLAND

The only state or territory to experience an increase in fatal crashes during the COVID period was Queensland (from an average of 111 in 2017–2019 to 123 in 2020). Comparison of Queensland fatal crashes and fatalities from 2017–2019 with those in 2020 revealed that:

- Queensland experienced a 30% increase in night-time fatal crashes but no change in daytime crashes.
- The fatal crash increase was evenly distributed across weekdays and weekends.
- The crash increase was confined to 50–80 km/h speed zones.
- The number of fatalities increased for passengers, pedestrians and pedal cyclists but not for drivers.
- Fatalities increased for most age groups.
- The fatality increase was greater for females (39%) than for males (7%).

ABS remoteness codes were not available in the Australian Road Deaths Database for crashes in 2017. Comparison of remoteness codes for fatal crashes in 2018–2019 with those in 2020 revealed that the increase in fatal crashes in Queensland was confined to Major Cities of Australia (i.e. Brisbane, Gold Coast, Sunshine Coast and surrounds) (+32%), with little change in the remainder of Queensland (–1%).

It is worth remembering that the numbers of crashes and fatalities are small, so many of the changes seen during the COVID period may not be statistically significant.

FATAL CRASHES IN VICTORIA BY REGION AND CRASH TYPE

Table 4 compares changes in SCATS vehicle detections and fatal crash counts for 2019 and 2020, the two years for which vehicle detection counts were available. For Victoria as a whole, the reduction in fatal crashes (18%) was less than the reduction in SCATS counts (27%). However, the outcomes differed markedly between Melbourne and the remainder of the state:

- In Greater Melbourne, the drop in fatal crashes (34%) was greater than the drop in vehicle detections by SCATS (28%).
- In the Rest of Victoria, the number of fatal crashes increased by 4%, despite a drop of 19% in vehicle detections by SCATS.

ABS Region	SCATS count change	Fatal crash change
Greater Melbourne	–28%	–34%
Rest of Victoria	–19%	+4%
Whole of Victoria	–27%	–18%

Table4 changes in SCATS vehicle detections and fatal crash counts for 2019 and 2020

The Australian Road Deaths Database classifies fatal crashes as single vehicle (including pedestrian crashes) or multi-vehicle. Despite the reduced proportion of Victorian fatal crashes occurring in Greater Melbourne during the COVID period, the proportions of Victorian fatal crashes classified as single vehicle (57%) and multi-vehicle (43%) did not differ between the pre-COVID period (March–August 2017–2019) and the COVID period (March–August 2020).

FATAL BICYCLE CRASHES

The only road user group to experience an increase in fatalities nationally during the COVID months was pedal cyclists (from an average of 21 in 2017–2019 to 27 in 2020). Anecdotal accounts suggest there was a substantial increase in cycling during the COVID period, which is likely to have contributed to the increase in cyclist fatalities. The distribution of cycling across roads versus off-road paths is not known.

Examination of cyclist fatalities in the BITRE data reveals that:

- The increase in cyclist fatalities was confined to cyclists in multi-vehicle crashes (+44%). There was a very slight decrease in cyclist fatalities in single vehicle crashes.
- The increase was confined to crashes NOT involving a bus, rigid truck or articulated truck.
- We have no information about the types of light motor vehicles involved in the crashes.
- The increase in cyclist fatalities was confined to Queensland and Victoria. There was little change in other jurisdictions.
- The increase was confined to weekdays (+40%), with no change on weekends.
- The increase was mainly in major cities and in 50–80 km/h speed zones.
- The increase was confined to cyclists aged 0–16 and 40–64. There were no increases in other age groups.

DISCUSSION

Proxy data for exposure, including petrol sales across Australia, South Australian traffic volume data, vehicles detected at signalised intersections in Victoria and driving trips reported in online surveys all indicate that driving exposure was reduced between 20% and 30% during the COVID period.

Based on data available at the time of the study, it appears the decline in fatal crashes during the COVID period was substantially smaller than the decline in motor vehicle use.

The increased number of deaths of pedal cyclists at a time of reduced fatalities among other road user groups warrants further investigation. Possible contributing factors include an increase in on-road cycling, particularly among inexperienced cyclists, possibly resulting from concerns about risk of infection when using public transport.

Measures likely to yield further reductions in fatal crashes include:

- Improved infrastructure on urban and regional roads
- Enforcement technologies that can be deployed as deterrents to unsafe driving behaviour
- Mandating the use of warning or ignition interlock systems that are readily available on vehicles sold today and can discourage or prevent speeding, drink driving, non-wearing of seat belts and rear end crashes.

A key limitation of the study is that complete data on serious injury crashes during the COVID period (March to August 2020) will not be available until 2021 at the earliest. Analyses for this investigation were therefore limited to fatal crashes. In addition, exposure data (vehicle-kilometres travelled) were not available, necessitating the use of proxy measures, such as petrol sales, vehicle counts and self-reported number of trips taken.

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CONCLUSIONS

The national reduction in driving exposure during the COVID period cannot be accurately quantified using presently available data, but several indicators suggest the exposure reduction is very likely to be substantially greater than the 10% reduction in fatal crashes observed during the same period. Thus it appears that reductions in traffic volume do not automatically lead to a commensurate reduction in fatal crashes.

The increase in cyclist fatalities during the COVID period is suggestive of a possible increase in on-road cycling.

ACKNOWLEDGMENTS

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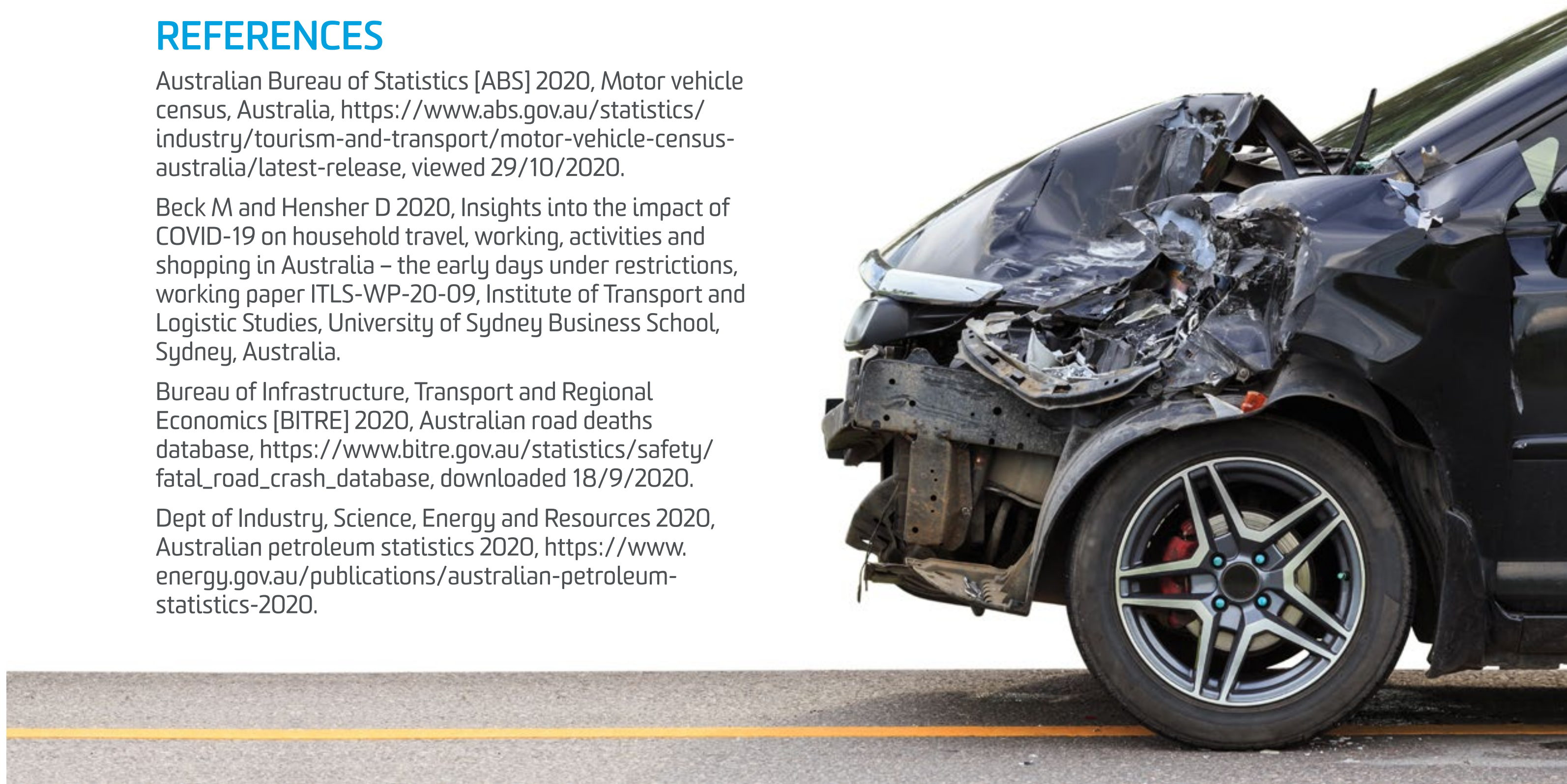

FACTORS INFLUENCING THE USE OF ON-DEMAND, SHARING-ECONOMY MOBILITY PLATFORMS, POOLED AND AUTOMATED SERVICES IN AUSTRALIA

While ride-hailing has become ubiquitous in most cities, there is a dearth of studies using individual survey level data to better understand what drives the demand for such services.

Understanding consumer motivations and preferences is not only critical to the sharing platform but also to their rivals who want to retrieve or gain market share. While survey data provides a window into ride-hail travelers the implications are limited to the case study, with the majority in the US. Notably, the results of different studies across the world have yielded slightly different socio-demographic indicators as travelers in different regions may possess different attitudes towards this new mode of transport.

These differences necessitate country-specific studies and ours is the first investigating the characteristics of ride-hailing travelers in Australia. Furthermore, the ride-hailing studies to date are by and large based on metropolitan demand and do not shed light on differences if any that exists between metropolitan and regional areas.

This paper contributes to this knowledge gap by examining the regional/metropolitan dimension in the factors influencing the frequency of ride-hailing use and the demand for pooled and autonomous vehicle (AV) rides in Australia. Through individual-level survey data, we found that there is indeed a divide between factors affecting not only the frequency of using ride-hailing in the status quo but also in the future adoption of new services of pooled and AV-based services.

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INTRODUCTION AND BACKGROUND

The success of on-demand sharing economy ride-hailing platforms such as Uber in recent years has rapidly disrupted the traditional taxi market. As of June 2020, Uber operates in more than 700 cities across 63 countries, with about 14 million daily trips, 91 million active passengers and 3.9 million drivers. Australia is no exception. According to a 2019 nation-wide survey commissioned by the Victorian Government in Australia, the ride-hailing platform is the second-largest platform (about 24.8%) after Airtasker (34.8%) that is used by Australian residents.

With the growing demand for ride-hailing services, ride-hailing companies are recently offering a pooling (ride-splitting) option such as UberPool in some cities. Pooled services with relatively lower costs have the potential to draw users from active/public transit modes and increase vehicle occupancy. Such services can be used for door-to-door trips, and/or for first- and last-mile connectivity to transit hubs (if they are available in lower cost and well-integrated). Nevertheless, the fundamental question here rests on the key factors that make people to embrace these shared economy services (that is, pooling rides with others for passengers or a mix passenger-parcel delivery), and how these services should be subsidized to provide a complementary and/or substitution, when necessary.

Also, with the emergence of autonomous vehicles, AV ride-hailing rides will become a reality soon. Given the benefits, start-up industries have already taken steps towards this future, and it is likely that local markets will also opt for such technological changes. While it is known that the shared economy and the disruptive technologies will be increasingly relevant to the transport sector, the impact is not yet well understood, particularly on-demand services. Many issues regarding privacy concerns, equity, accessibility, digital and regional divide remain unaddressed.

While ride-hailing has become ubiquitous in most metropolitan areas, it is still unclear how it prevails in the regional areas, especially after the emergence of new services of pooling or self-driving rides. In this paper we attempt to address these knowledge gaps.

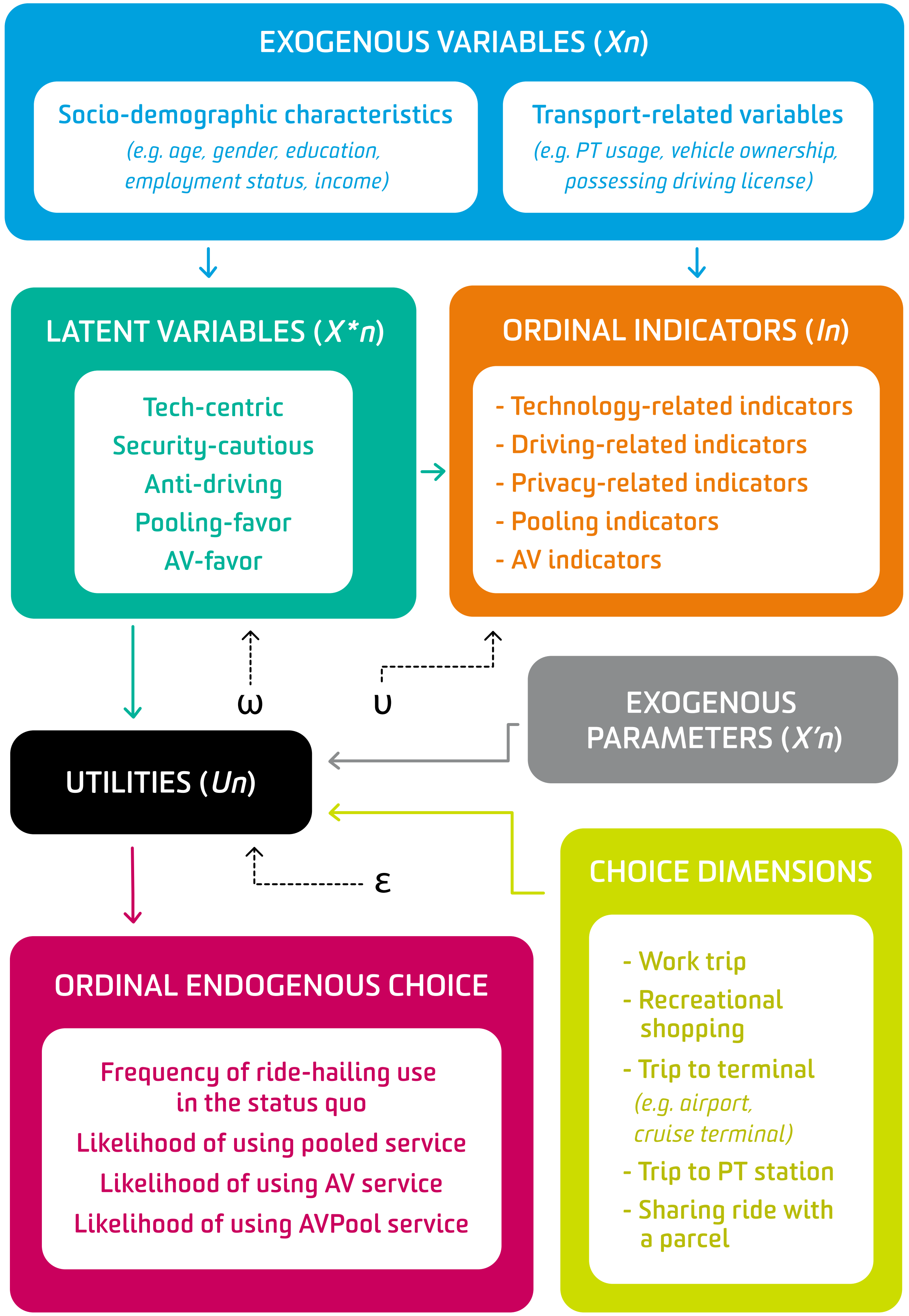
METHODS

In mid-2019, we conducted a web-based survey administrated by a survey sampling firm in the Australian states of South Australia, Queensland, Tasmania and Western Australia who have used/are familiar with ride-hailing platforms including Uber. These states were chosen as - unlike New South Wales and Victoria - Uberpool (shared ride-hailing trips) had not begun to operate, and one aim of our survey was to gather stated preferences for this particular feature. In addition, responses from residents in both metropolitan and regional areas in these states were obtained. The survey collected 777 complete questionnaires (406 metropolitan and 371 regional) in five Australian states. According to the Australian Bureau of Statistics (ABS), metropolitan areas represent Greater Capital City Statistical Areas, and regional areas identify the rest of state. These are geographical areas that have been identified by the ABS based on the functional or socio-economic characteristics of these areas. The sample was chosen to represent the most recently available 2016 Australian population census by age and gender demographics. This was done using screening questions related to gender and age in the beginning of the survey, which was administrated by the survey sampling firm.

Developing an integrated latent variable and ordered logit models, as shown in Figure. 1, we investigated five research questions to identify: (i) the determinants of the frequency of ride-hailing use in the status quo; (ii) the likelihood of adopting pooled ride-hailing services; (iii) the likelihood of adopting AV ride-hailing services; and (iv) the likelihood of adopting AVPool ride-hailing service.

49% - 57% of Australians are likely to use pooled ride-sharing for work and recreational trips. This likelihood rises slightly for trips to airports or similar mobility hubs.

Figure 1: – Schematic model structure



Factor analysis was undertaken to re-identify the number of unobserved behavioural factors from the indicators based on their interdependencies. The latent variable Tech-centric is defined with the indicators of favouring technology. Individuals from metropolitan areas are by and large in favour of technology. Notably, several indicators dropped out in the regional dataset. The latent variable of Anti-driving represents the main reasons of using Uber, namely the lack of accessibility of PT, scarcity and expensive parking. The indicator of 'Using Uber due to being unable to drive due to alcohol' dropped out from the Anti-driving latent variable in the metropolitan dataset. The latent variable Security-cautious represents the indicators related to concerns. There is no significant difference between individuals from regional and metropolitan areas in terms of their concerns using such platforms. Similarly, two latent variables given by Pro-Pooling and Pro-AV were defined with indicators favouring the pooled and AV ride-hailing services. These two latent variables were only used in the model estimations of pooled and AV-based ride-hailing adoption.

RESULTS

The results obtained in this study provide some key insights and policy implications.

PUBLIC TRANSPORT VS RIDE HAILING

Results indicated that PT commuters are more likely to use ride-hailing frequently in both regional and metropolitan areas.

This implies that those who have already given up door-to-door driving have greater tendency to switch to ride-hailing. Given the door-to-door convenience and relatively lower waiting time and cost, this may lead to PT substitution in the near future, which is particularly concerning for city planners, given the externalities of ride-hailing such as deadhead mile travelled, increasing congestion and pollution.

Given the substitution of ride-hailing and pooled ride-hailing with PT in metropolitan areas leading to a fall in demand for PT, governments need to rethink their policies, budgetary concerns and infrastructural planning in moving forward to ensure that PT does not remain underutilised and thereby cost-inefficient. In the rural areas however, taxis as a form of substitute for ride-hailing need to consider competitive pricing or some form of price discrimination (different pricing strategies for different services/routes) and improve their services to raise customer satisfaction to lure users away from ride-hailing.

PT VS POOLED RIDESHARING

The results also showed that the regional multimodal PT travellers and metropolitan residents with tech-centric and anti-driving attitudes are more likely to adopt pooled services for all four trip purposes.

Given these two latent attitudinal constructs are correlated with being a PT user, it implies that pooled ride-hailing services may substitute PT in the future. While pooled ride-hailing has the potential to take on a paratransit mobility role, it is not clear how sustainable this is compared to PT and active transport.

Our survey showed that 49% -57% of Australian metropolitan or regional residents are somewhat or extremely likely to use pooled ride-hailing services for work and recreational trips. This percentage is slightly higher for trips to airport or a cruise terminal where 62% and 63% of regional and metropolitan residents are somewhat or extremely likely to use such services.

FACTORS AFFECTING ATTRACTIVENESS OF POOLED RIDESHARING

The survey also provides insight on the effect of ride attributes making pooled services attractive and identifies areas in which PT can be improved to lure commuters away from ride-hailing.

It was found that walking distance to/from pick up/drop off points is likely to be a deterrent factor in metropolitan work-related and trips to terminals, while it is only significant in the latter for the regional residents.

Delays were more significant barriers in regional recreational trips and priority drop off were influential in attractiveness of metropolitan trips to terminals.

In terms of the number of passengers and price discount, it did matter for regional work-related trips and for metropolitan terminal trips, where sharing with two passengers at 50% discount increased the likelihood of sharing a ride.

ATTRACTIVENESS OF AV RIDE-HAILING SERVICES

The results indicated that AV ride-hailing services are likely to be considered as a mobility option by regional and metropolitan residents, and the latter are likely to do so for trips to PT stations.

It was found that regional residents with tech-centric attitudes and metropolitan residents with anti-driving attitude are more likely to use AV-based services for all trips' purposes. This implies that AV uptake in regional areas is likely to be correlated with being young, female, multimodal traveller and car owner. While AV uptake in metropolitan areas is more likely among those who driving is not their first choice either due to difficulty or cost of parking, stress of driving, or not being able to utilise travel time more effectively. Notably, this group are multimodal PT users in the status quo and the likelihood of substituting PT with AV ride-hailing service could bring about further externalities in the near future in our metropolitan areas, if PT fails to keep its market share. However, the stated intention to swap ride-hailing with AV ride-hailing showed that around 40% of metropolitan residents and more than 50% of regional residents would not choose AV service, even with price discounts up to 50%. This indicates a potential problem in AV uptake in Australia.

On the other hand, ride-hailing companies wanting to promote pooled services should note concerns related to walking distance to pick up points and devise some incentives perhaps in the form of loyalty points to encourage customers to utilise this service. With the AV option, ride-hailing platforms should not be ambitious and embark on this on a grand scale but rather to complement commute trips to PT stations.

ATTRACTIVENESS OF AV POOLED SERVICES

The results highlight the unlikely adoption of AVPool services by the majority of metropolitan and regional residents. While metropolitan PT users/commuters are more likely to adopt AVPool for recreational and trips to terminals, the only factor that may increase the uptake by regional residents is an anti-driving attitude. The stated intention to swap pooled services with AVPool was be similar to AV adoption.

OTHER FINDINGS

Our results showed that in metropolitan areas, ride-hailing can replace PT with a higher percentage in metropolitan areas while in the regional areas the substitution of private cars occurs with a higher percentage. Expectedly, taxi is another major competitor. Ride-hailing has also induced a more significant reduction in active mode usage and only a small percentage stated that ride-hailing had increased their use of PT, walking or biking, which reflects the complementary role of ride-hailing in low PT accessibility regions. By and large, these results confirm the finding from previous studies that ride-hailing may have negative externalities as a result of deadheading, increased vehicle kilometres travelled, creating extra trips and substituting from more sustainable modes such as active transport modes and PT. On the other hand, it may bring about some positives impacts, such as reducing the demand for parking and car ownership.

Lastly, in line with the literature, younger generations are more likely to share the ride either with fellow passengers or a parcel and are also more likely to adopt AV services.

CONCLUDING REMARKS

Notably, this one-off survey only provides a snapshot about the perceptions of respondents towards the pooled services. It has however, shown that the impact of ridesharing in all its forms on transport usage and patterns is complex.

Larger sample size and preferably a panel data analysis should be deployed in future research to provide clearer policy and forecasting implications.

These perceptions may change once the technology is up and running, as Ian Ayres says:

"Humans not only are prone to make biased predictions, we're also damnably overconfident about our predictions and slow to change them in the face of new evidence. In fact, these problems of bias and overconfidence become more severe the more complicated the prediction."

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SMART CITY PARKING OPTIMISATION EVALUATION

ARRB was able to help Mornington Peninsula Shire Council (MPSC) demonstrate to its stakeholders, community and project funders that their investment was well made, delivering significant traffic and economic benefits. This was shown through a combination of interview techniques, traffic data analysis and economic modeling and assessment. MPSC has a track record in innovating in the transport arena, so we look forward to working together in the future, and helping local traders and visitors have a great day out at the beach.

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INTRODUCTION

Most Australians associate summer with school holidays, major outdoor sporting events and long summer days. Many also remember childhood visits to the beach, which promised a day of sun, fun, surf and sand. For our forbearing parents, there was an additional dimension less looked forward to, that of driving around in the hot sun looking for a parking spot close enough to the beach of choice to avoid complaints and to allow easy ferrying of beach paraphernalia to and from the beach.

Mornington Peninsular Shire Council (MPSC) were aware of this potential barrier to visitors; with beaches all along the Port Phillip Bay coastline, there was a need to ensure a high market share of visitors was maintained for the local economy.

MPSC therefore approached the Federal Government through the Smart Cities and Suburbs Program and secured funding for a demonstration project titled The Mornington Peninsula Smart Parking and Amenities at High-demand Areas. Using Rye as the demonstration township, the idea was to address growing demand on parking and amenity facilities in towns with particularly high number of tourist attractions, and in so doing be more attractive a destination than neighbouring areas.

A critical part of the project was an evaluation of the outcomes; would future investment in the concepts and technologies trialled deliver the transport outcomes desired?

ARRB was engaged by the Mornington Peninsula Shire (MPS) to answer this question in order to ascertain the project outcome and its impact on the community.

This article gives an overview of what MPS implemented, how the effectiveness was evaluated and the findings of this evaluation.

THE IMPLEMENTED SYSTEM

Rye is located towards the Southern end of the Mornington peninsula and is a popular destination for day trips from Melbourne's Eastern and South Eastern Suburbs. It is roughly 100km from Melbourne's CBD by road. Its location relative to nearby major centres is shown in Figure 1.

The critical components of the scheme were

- Vehicle detection sensors – dual infra-red and magnetic sensing – in car parks
- Associated data aggregators and distributors
- Variable Message Signs (VMSs) located on the major routes into the precinct advising of parking availability

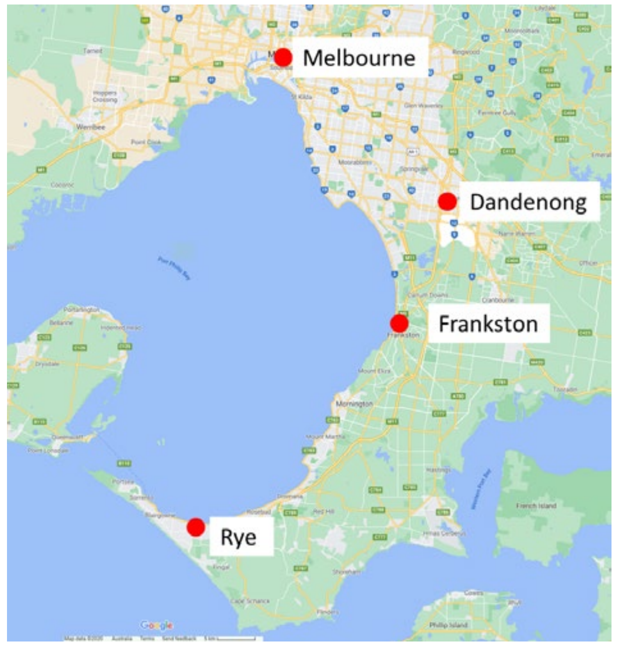

Figure 1 Geographic context of Rye

Source Google Maps 2020, 'Rye, Victoria', map data, Google, California, USA.

ARRB'S EVALUATION OF THE SCHEME

ARRB was engaged to provide the overall project evaluation to ascertain the project outcome and its impacts on the community. A before-after comparison was designed and conducted to assess the following expected outcomes of the project:

- Evaluate the impacts on the community of installing a smart parking management package, including smart parking signage and parking app as a key as well as smart parking sensors
- Support the development of business cases, i.e. expand the pilot project to the broader council area in the future
- Support sustainable funding to maintain the smart parking and pedestrian facilities.

Parking improvements achieved have the potential to increase revenue to local shops by more than $150,000 over the peak season.

The 'before' and 'after' periods are defined as follows:

- 'Before' period (March 2019): Saturday 9 March until Monday 18 March 2019
- 'After' period (March 2020): Saturday 7 March until Monday 16 March 2020.

Additional 'after' data was also collected during the January peak season - Saturday 18 January until Monday 27 January 2020 - to enrich the assessment and provide insight into a busier period of the year compared to March.

The following data collection and evaluation methods were applied:

- Evaluation of the project success based on the intercept survey data obtained from road users in March 2019 and March 2020 (before-after comparison)
- Evaluation of the project success based on traffic data (including vehicle speeds and volumes) in March 2019 and March 2020 collected from tube counters installed in key locations in Rye (before-after comparison)
- Evaluation of additional 'after' data obtained during the peak-season weekend in January 2020 (both survey and traffic data), and comparison to March 2019 data
- Assessment of impacts of the parking and traffic situation on local retailers and drivers/passengers.

SURVEY DESIGN AND DATA COLLECTION

In consultation with the project board members and MPS experts, ARRB developed an intercept survey questionnaire that covered a set of key questions. Respondents were asked about their perception of the traffic and parking situation in Rye town centre (e.g. time savings, perceived congestion, safety) and how they felt about the amenities in the area. The questionnaire also included some background and demographic questions (age, purpose of travel, visitor or resident etc.). It was expected that the subjects would spend 10–15 minutes to complete the survey.

The intercept surveys were conducted in March 2019 and March 2020 targeting as many people as possible within the survey period at Rye town centre and foreshore. The survey covered nine observational sites. Survey hours were from 10 am to 6 pm.

The surveys were conducted on the Saturday and Sunday of the Labour Day long weekends ('before': 9 and 10 March 2019; 'after': 7 and 8 March 2020). It was intended to collect data on busy weekends where high demand for parking is usually observed. A total of nine areas at the foreshore park and town centre were covered (see Figure 2), and a total of 246 respondents were surveyed.

TUBE COUNTER DATA COLLECTION

The six sites in Rye where tube counters were installed were:

The eastern and western tube on Point Nepean Road (tubes 1 and 3) as well as the southern tube on Dundas Street (tube 5) captured traffic entering or leaving Rye on the three main roads leading east, west and south.

Additional tubes were installed within Rye on Point Nepean Road near the town centre (tube 2), on Dundas Street near the intersection with Point Nepean Road (tube 4) and on Nelson Street near the Nelson Street parking area (tube 6).

For each of these locations, data - Vehicle volumes, speeds and vehicle composition - for both directions of travel was obtained.

The tube location and location of VMS are shown in Figure 3

Figure 2 Areas in which intercept surveys were conducted
Source Austraffic (2019).

*Note: Red areas: foreshore car parks; green areas: foreshore pedestrian zones; yellow areas: streets and town centre.

Figure 3 Location of traffic counting equipment and VMSs
Source Google Maps 2020, 'Rye, Victoria', map data, Google, California, USA.

KEY FINDINGS

FINDINGS FROM THE INTERCEPT SURVEY

Respondents generally saw improvements during both 'after' periods (January 2020 and March 2020) compared to the 'before' period (March 2019). This includes less time spent to find parking, increased easiness to find parking and lower perceived congestion levels. Even in January 2020, improvements in major surveyed questions were also noticeable in the survey data despite high peak season traffic volumes. The highlighted findings are:

- The percentage of respondents who spent more than 5 minutes to find a parking spot dropped from 31% in March 2019 to 14% in January 2020 and further down to 3% in March 2020. The percentage of people who spent more than 10 minutes to find a parking spot dropped from 15% in March 2019 to 6% in January 2020 and down to 0% in March 2020.
- In March 2019, 26% of the respondents reported it was difficult or extremely difficult to find a parking space, whereas in January 2020 this figure dropped to 12%. By March 2020, no one found parking difficult.
- In March 2019, 48% of the respondents reported they experienced medium to heavy congestion when driving through the town centre. This figure dropped to 30% in March 2020.
- The vast majority (> 90%) of respondents thought that parking was safe. There was no considerable change between March 2019, January 2020 and March 2020. Only a few respondents had some concerns or thought it was dangerous (valuables stolen from car, narrow parking spaces, more cameras required to monitor the situation).
- When asked about their suggestions for how to further improve parking in Rye, in March 2019, more than half of respondents (55%) suggested that more parking spaces were required, especially on busy days during the peak season. This figure was only 20% in January 2020 and down to 15% in March 2020. Other suggestions included better car park design and more parking guidance
- The parking guidance VMSs were considered helpful by both visitors and locals. In January 2020, 55% of the respondents noticed the signs when driving into Rye, and 40% of them stated that the signs did help them to find parking faster. By March 2020, 62% of the respondents reported that they saw the parking signs when driving into Rye, and about half of them (49%) stated that the signs did help them to find parking faster. However, both January and March 2020 surveys showed that the parking app was not used or the respondents were not aware of it.

TIME SPENT TO FIND PARKING

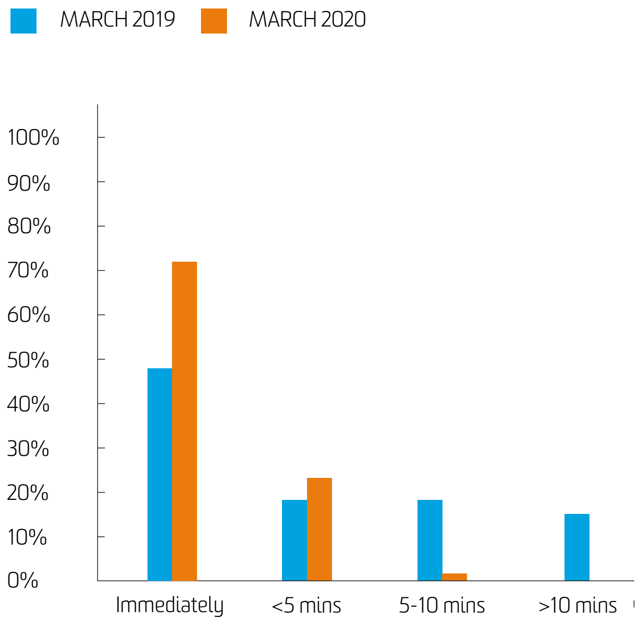

Figure 4 Examples of changed perceptions of interviewees in intercept surveys (time spent to find parking)

FINDINGS FROM THE TRAFFIC REPORT

Traffic volumes and speeds were collected from six tube sites along Point Nepean Road, Dundas Street and Nelson Street for both the 'before' period (9 March to 18 March 2019) and two 'after' periods (18 to 27 January 2020 and 7 to 16 March 2020). The key findings were:

- Traffic volumes increased during both 'after' periods (January and March 2020) compared to the 'before' period (March 2019). Average weekend volumes in March 2020 were 2.3% higher on average than in March 2019. In January 2020, they were 26.9% higher, i.e. considerably higher traffic volumes were recorded during the peak season period in January 2020 compared to March.
- Mean speeds decreased slightly during both 'after' periods compared to the 'before' period. However, speed decreases were small in March 2020 on the average weekend, and they were mostly statistically insignificant (only 4 out of 12 cases are significant). The speeds dropped more significantly in January, which corresponds to the higher traffic volumes in January compared to March.
- The speed variability and CoV of the mean speeds was lower in most cases on weekends during the 'after' periods compared to the 'before' period (10 out of 12 cases for March 2020 vs March 2019, and 9 out of 12 cases for January 2020 vs March 2019 comparison), despite the increased traffic volumes and lower speeds. The decreased covariance (CoV) indicates a more homogeneous/less variable traffic flow or less stop-and-go type traffic along the major routes, i.e. the traffic flow had improved on weekend days, which is the key period for a holiday destination such as Rye.

EASINESS TO FIND PARKING

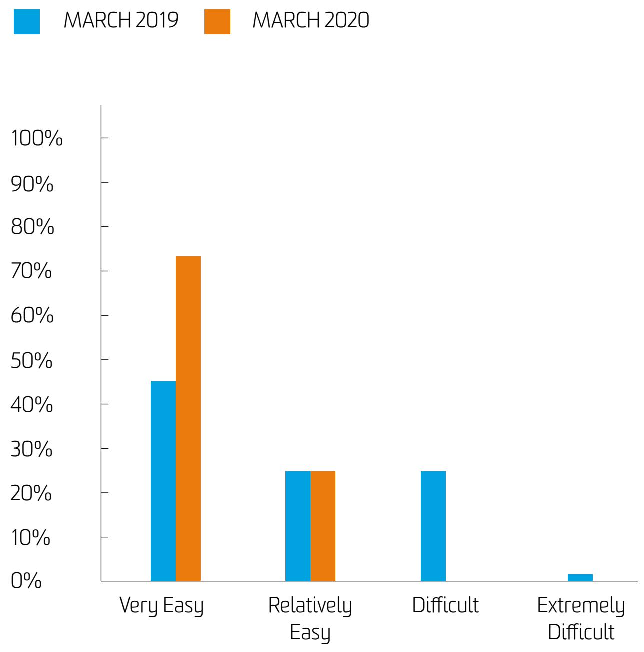

Figure 5 Examples of changed perceptions of interviewees in intercept surveys (easiness to find parking)

MEASURED SPEED DIFFERENCES

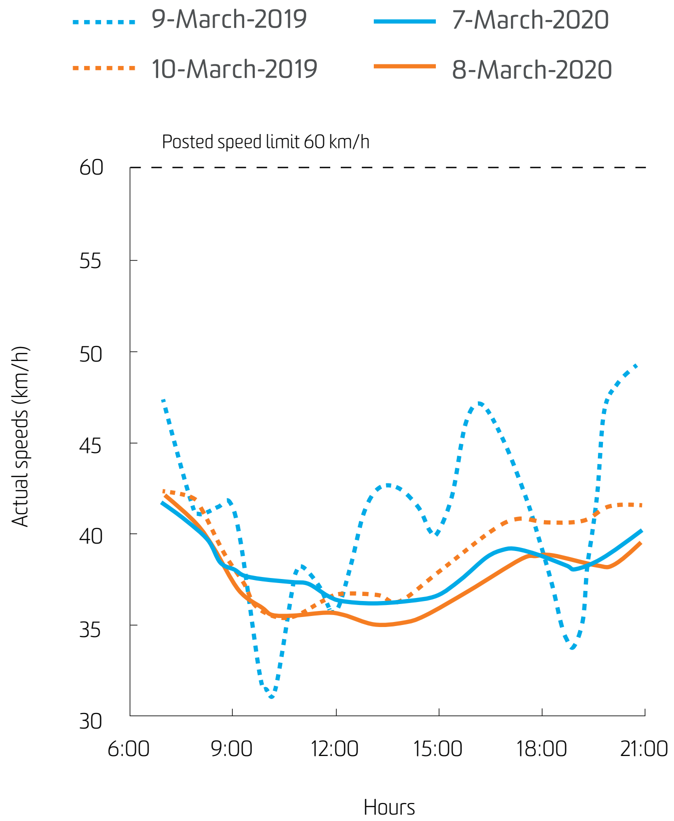

Figure 6a Examples of measured speed differences Northbound on Dundas street

MEASURED SPEED DIFFERENCES

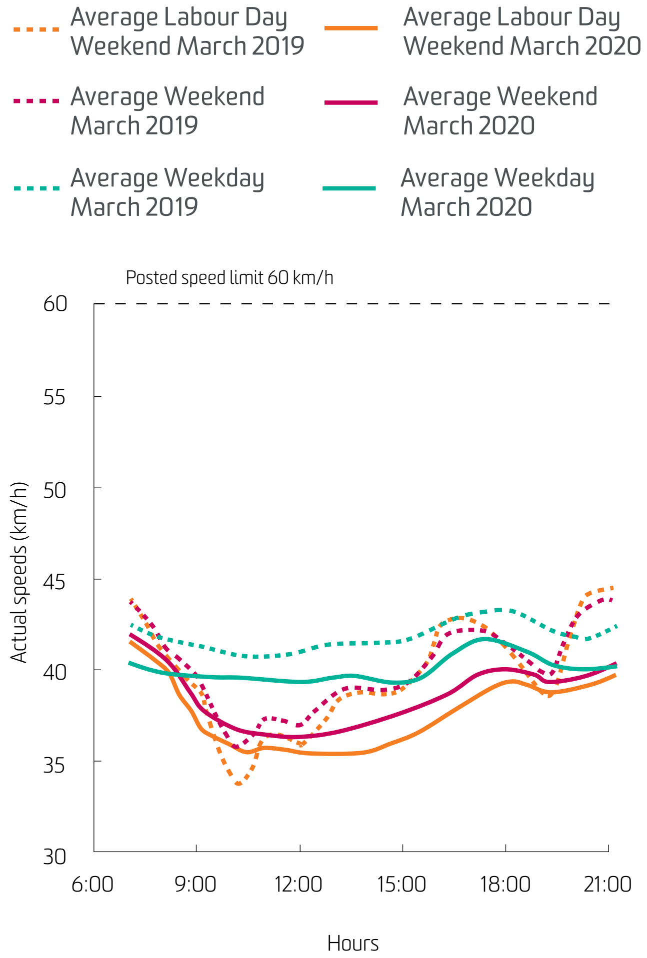

Figure 6b Simplified examples of measured speed differences Northbound on Dundas street

ECONOMIC OUTCOMES

As stated earlier, supporting the local economy was an important driver of this project, through making Rye a more attractive destination than similar towns by dint of its improved traffic and parking performance. The results described above show that subjectively patrons of the Rye foreshore and shopping precincts felt the smart city project had improved matters, and the tubes showed objectively that their perceptions were based on measurable differences too.

In addition, MPSC wanted to understand if the technology deployed could be used to improve economic outcomes for traders, by ensuring that the occupancy of parking spots was turned over as much as possible; i.e. reducing overstays in order to increase the number of visitors with access to the shopping precincts. In addition, they wanted to know what travel time savings the system was providing to visitors.

An economic assessment along these lines found that

- The potential additional retail revenue for shops in Rye was estimated at A$154 989 for the peak season between mid-December and late-January if parking overstays could be mitigated.
- The community saved travel time cost of A$20 037 over two weekend days by reducing the time to find a parking space by just over one minute.

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SUMMARY

ARRB was able to help MPSC demonstrate to its stakeholders, community and project funders that their investment was well made, delivering significant traffic and economic benefits. This was shown through a combination of interview techniques, traffic data analysis and economic modelling and assessment. MPSC has a track record in innovating in the transport arena, so we look forward to working together in the future, and helping local traders and visitors have a great day out at the beach.

THE DEVELOPMENT OF AUSTRALIA'S FLEXIBLE PAVEMENT ROAD DETERIORATION (RD) MODELS

The long-term pavement performance (LTPP) observational study conducted from 1994 to 2018, in conjunction with the accelerated loading facility (ALF) experimental data, has developed robust deterministic mechanistic-empirical road deterioration models for the gradual deterioration phase for flexible pavement arterial roads in Australia.

The RD models for rutting and roughness have statistically significant explanatory variables that cover potential changes in traffic load, climate and surface maintenance treatments. These models, along with the cracking and structural deterioration models are being adapted, by means of local calibration and adjustments, to PMSs operated by state road agencies for their arterial road networks. The local calibration can account for local conditions of pavement drainage and soil moisture as well as the reactive nature of some soils.

A recent upgrade of the rutting and roughness RD models, using relative performance factors for surface maintenance treatments, accounts for the discrete impact of different surface maintenance treatments on the rate of deterioration. This has improved the utility of the RD models that no longer rely on an estimate of the average annual surface maintenance expenditure ($/lane-km) variable, me, based on the year 2000 costs.

As noted, the RD models will be further refined by 2022 with additional LTPP observational data from Australia and New Zealand.

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BACKGROUND

The prediction of pavement performance is critical when using a pavement management system (PMS) for estimating maintenance and capital funding requirements for road networks. In the past many of the performance prediction models, such as the World Bank's HDM models, used in PMSs in Australia were based on data collected in Brazil, the Caribbean and Kenya from 1971 to 1984 (Cox 1990). Most of these models were not suited to Australian conditions of construction, maintenance, climate and traffic as sprayed bitumen sealing over an unbound crushed rock base occurs mainly in Australia, New Zealand and South Africa.

The United States (US) long-term pavement performance (LTPP) program started in 1987 as part of the Strategic Highway Research Program (SHRP), a five-year applied research program funded by 50 US states and managed by the Transport Research Board (Crawley 1997). After the SHRP ended in 1992 as planned, the LTPP program continued under the leadership of the Federal Highway Administration (FHWA) until the present time and is expected to remain active for many more years to come.

OBSERVATIONAL STUDY

ARRB was directly involved in the SHRP-LTPP in 1994 when Australia set up its own LTPP program under Austroads funding to monitor a range of pavement test sections under various traffic and climatic conditions. These sections, typically 100m to 200m long, included sites set up to be in line with the US SHRP, as well as those established in tandem with past Accelerated Loading Facility (ALF) trials undertaken by ARRB. While the Australian LTPP sites were relatively few, the intention was to use these sites as reference sites to 'calibrate' the performance of Australian pavements against the vastly numerically superior US SHRP study (over 2000 sites) (Clayton & Styles 2001).

Seven initial SHRP-LTPP and eight ALF-LTPP sites in Victoria, New South Wales and Queensland were established in 1994/95 by ARRB. A further eight long-term pavement performance maintenance (LPTTM) sites, each with five x 200m long sections, were set up in 1999 by ARRB in Victoria, New South Wales, Queensland and Tasmania, to investigate the effects of surface maintenance treatments on pavement performance. More new sites, that were set up for other studies, were added to the LTPP program after 2001/02 as a cost-effective way to expand the monitoring program to cover a broader range of field sites. These sites were in the Australian Capital Territory (ACT), Victoria, New South Wales, Queensland and South Australia. These sites included a heavy-duty asphalt pavement study sponsored by the Australian Asphalt Pavement Association (AAPA).

Figure 1 shows a typical LTPP site 150m in length with signage on the Hume Freeway, Victoria. All LTPP and LTPPM sites were regularly monitored measuring roughness (IRI), rutting (mm), deflection (micron) and later cracking (%). The LTPP and LTPPM sites were part of the Austroads LTPP project observational study that

Figure 1 LTPP site and signage

ran from 1994 to 2018. The observational data collected for the project was compiled in a single dataset website.

EXPERIMENTAL STUDY

Apart from the observational data collected at these sites, the study included an experimental data collection using the accelerated loading facility (ALF) from 1999 to 2001 conducted on test pavements under controlled environmental conditions at Dandenong, Victoria (see Figure 2). The ALF experiments were aimed specifically at quantifying, in terms of roughness and rutting, the impact on pavement deterioration of surface maintenance treatments and increased axle loads (Martin 2010a, 2010b).

The results of these experiments were expressed in terms of the relative roughness and rutting performance factors for maintenance, rpfmiri and rpfmrut, and the relative roughness and rutting performance factors for increased axle load, rfpliri and rfplrut. These relative performance factors were applied to the observed values of roughness and rutting to supplement the observational data to increase the range of its variables for maintenance and axle loading changes. Both the observational and supplementary data were used to derive the road deterioration (RD) models for arterial road roughness and rutting.

Table 1 summarizes the relative performance factor estimates for various surface maintenance treatments and Table 2 summarises the relative performance factors for axle load increases.

MAINTENANCE TREATMENT (RELATIVE TO A DOUBLE SEAL)	MAINTENANCE TREATMENT RATIO	rpf_{mrut}	rpf_{miri}
Uncracked double seal (wet/dry	Uncracked double seal (wet/dry)/ uncracked double seal (wet/dry)	1.00	1.00
Uncracked single seal (wet/dry)	Uncracked single seal (wet/dry)/ uncracked double seal (wet/dry)	1.32	1.79
Uncracked single seal (dry)	Uncracked single seal (dry)/ uncracked double seal (wet)	1.16	1.47
Uncracked geotextile seal (dry/wet)	Uncracked geotextile seal (dry/ wet)/ uncracked double seal (dry/wet)	0.62	0.86
Cracked single seal (wet/dry)	100% cracked single seal (wet)/ uncracked double seal (wet/dry)	2.71	3.51
Cracked double seal (wet/dry)	100% cracked double seal (wet)/ uncracked double seal (wet/dry)	2.06	1.96

Table 1 Summary of estimated relative performance factors for maintenance treatments relative to a double seal
Source Martin 2010a.

	rpf_{lrut}	rpf_{liri}
Load ratio, LR = axle load / reference axle load	$(LR)^{2.248}$	$(LR)^{3.536}$

Table 1 Summary of estimated relative performance factors changes in axle load
Source Martin 2010b.

Figure 2 Accelerated Loading Facility (ALF) at Dandenong, Victoria.

ROAD DETERIORATION

NATURE OF PAVEMENT DETERIORATION

The three phases of road deterioration that occur over the passage of time and traffic load are shown in Figure 3. The first phase, initial densification, occurs within the first 12 months after the pavement is opened to traffic. Initial densification is apparent in certain forms of permanent distress such as rutting and roughness. Initial densification may also lead to an increase in pavement strength, but this is not usually accounted for in deterministic RD modelling.

The second phase of road deterioration, gradual deterioration, is the phase where most in-service pavements operate. Figure 3 shows that gradual deterioration proceeds at a low rate and is virtually linear. The third and final phase of deterioration is the rapid deterioration phase which is difficult to predict as the pavement approaches ultimate failure.

Pavement prediction of in-service pavement performance is in the gradual deterioration phase, involving the prediction of both road deterioration (RD) and the impact of works effects (WE) in maintaining acceptable levels of service to the road users, as shown in Figure 4. Both the RD and WE models, when incorporated in a PMS, are vital for use in estimating funding for medium to long term maintenance and enhancement works and predicting road wear costs associated with heavy vehicle use.

THREE PHASES OF ROAD DETERIORATION (RD)

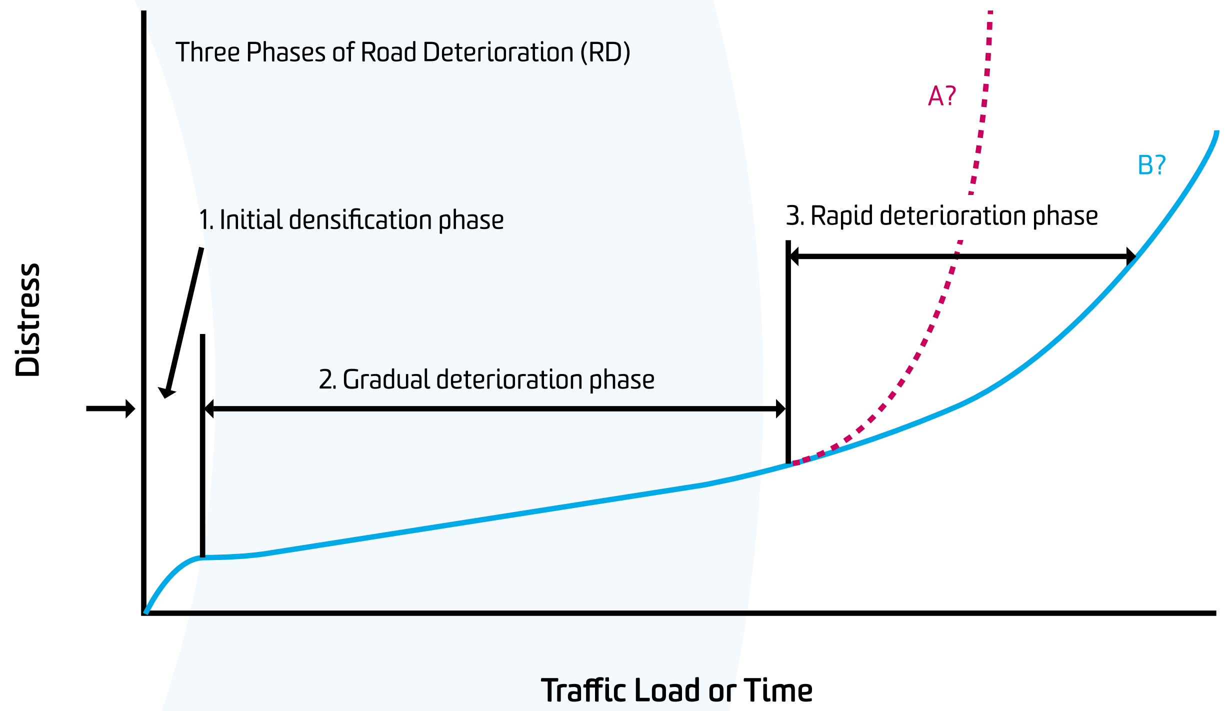

Figure 3 Three phases of road deterioration (RD).

THREE STAGES OF PAVEMENT PERFORMANCE

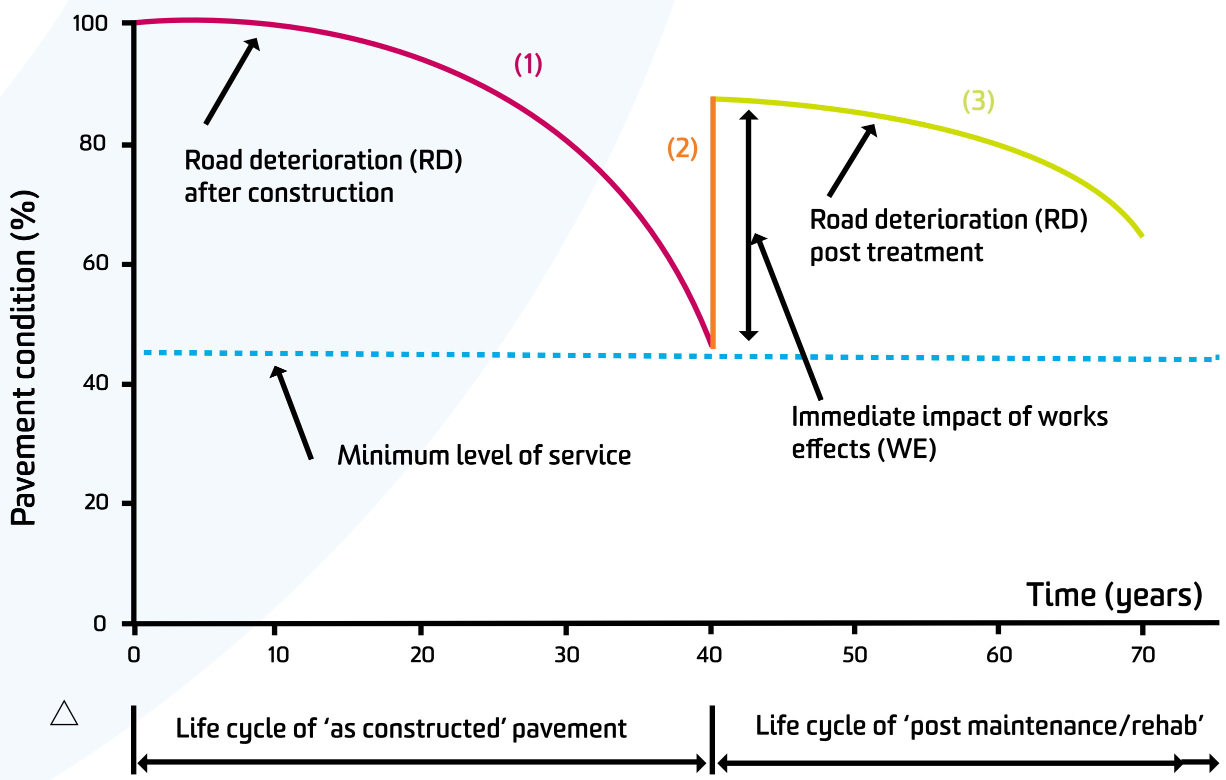

Figure 4 The three stages of pavement performance.

RD MODEL DEVELOPMENT

In the development of RD models some initial filtering of the LTPP/LTPPM observational datasets was needed to:

- Eliminate out of range variables and obvious data errors.
- Select deteriorating condition data for roughness, rutting and cracking RD models to ensure data is either stage (1) or stage (3) of deterioration.

The latter filtering is critical to ensure that data under deteriorating conditions are captured and not included with the works effects associated with rehabilitation (Martin et al. 2006). Similarly, for a time series of deflection data it is important to filter out reductions in deflection due to rehabilitation works. However, it has been observed that reductions in deflection can occur due to a warming climate and low rainfall. These observations need to be reviewed for the future refinement of the structural RD modelling.

The LTPP study published a range of road deterioration (RD) and works effects (WE) models from 2007 to 2017 (Austroads 2007, 2010a, 2010b, 2017) as well as many other related subjects such as, RD model calibrations, performance and design comparisons and the effectiveness of surface maintenance treatments (Austroads 2018).

CURRENT RD MODELS

The current RD models are deterministic mechanistic-empirically based for the gradual deterioration phase for flexible pavement arterial roads in Australia. These types of models are based on theoretical postulations about pavement performance, but can be calibrated, using regression analyses, by observational data (Lytton 1987). These models must adhere to known boundary conditions and physical limits. These models can incorporate interactive forms of distress during pavement life, such as the interaction of rutting with cracking, when these interactions are well understood. If these models are theoretically sound and correctly calibrated, they may be applied beyond the range of data from which they were developed.

The current version of the RD models, which are in a cumulative deterioration form (Martin and Choummanivong 2018), were built using cumulative distress observational data as a time series with each cumulative distress model fitted to the data by a multivariate non-linear regression analysis. For example, in Figure 5 the prediction of total rutting, rut(t), at time, t, is expressed by two main components as follows:

$$rut(t) = R0 + \sum \Delta rut(t)$$

where

$\sum$ $rut(t) =$ cumulative rutting at time 't' distress model (see Figure 5)

$= f(AGE, MESA, SNC, me, TMI)$

$R_0 =$ initial rut due to densification at time t = 1.

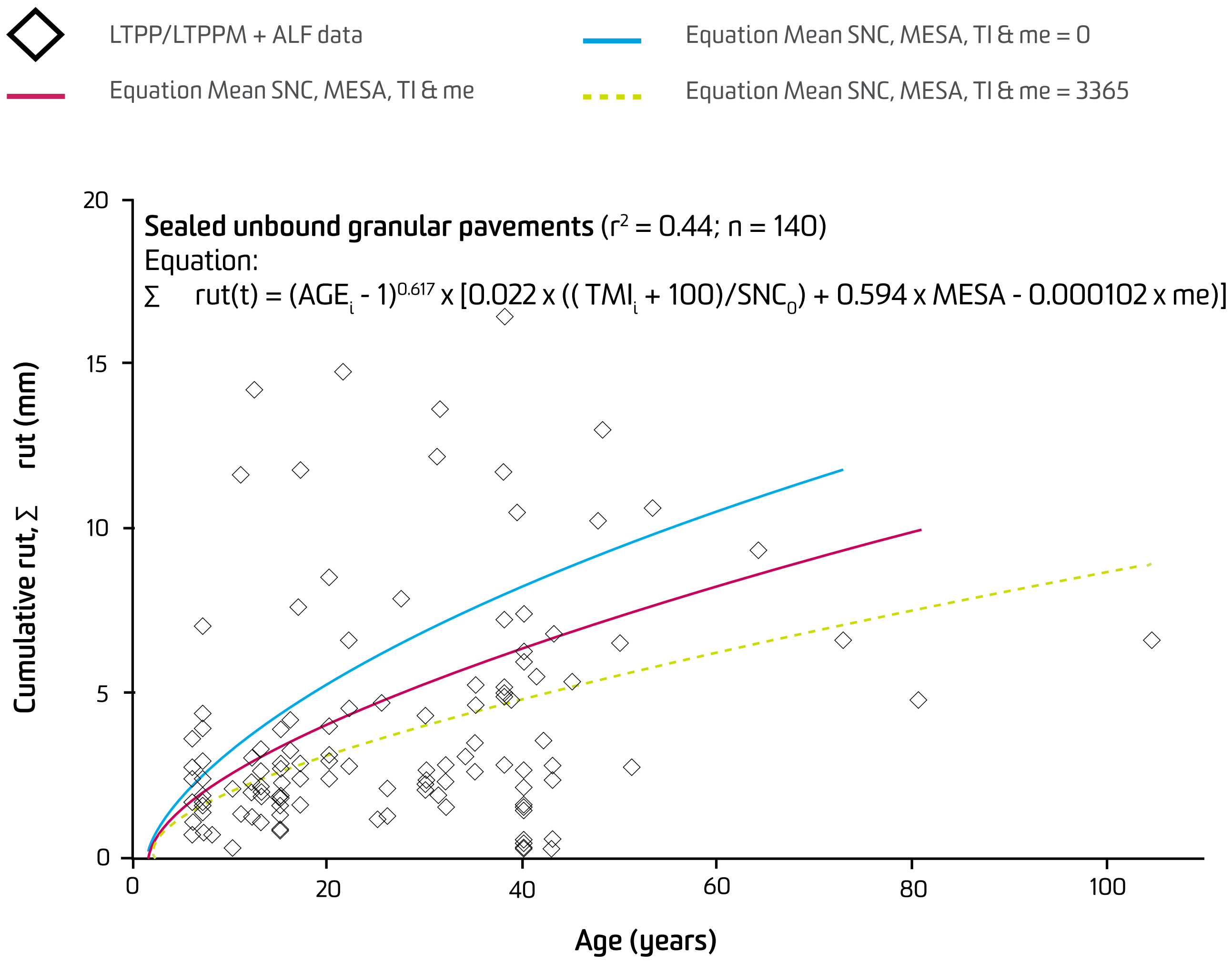

Figure 5 Structure of cumulative rutting model.

A significant benefit of the current models is that they include parameters that account for changes in heavy vehicle traffic loading, MESA, and climatic conditions, Thornthwaite Moisture Index, TMI (Thornthwaite 1948), as well as the composition and initial strength of the overall pavement/subgrade, SNCO, and maintenance surfacings covering the typical range treatments.

These models have had some refinements since they were published in 2010. The RD models for rutting and cracking have a degree of interaction with the RD model for roughness as shown in Figure 6. However, there is currently no direct interaction of the estimated current pavement/subgrade strength, SNCi, with the RD models for rutting and roughness because it was not supported by the observational data used to develop the models published in 2010.

The current RD models only include statistically significant independent variables, where statistical significance is determined by a Likelihood Ratio (LR) test for non-linear models or a Student 't' test for linear models.

More recently the relative performance factors for surface maintenance treatments, rpfmiri and rpfmrut, were directly used in the rutting and roughness RD models to replace the independent variable for annual maintenance expenditure, me (Martin and Choummanivong 2021).

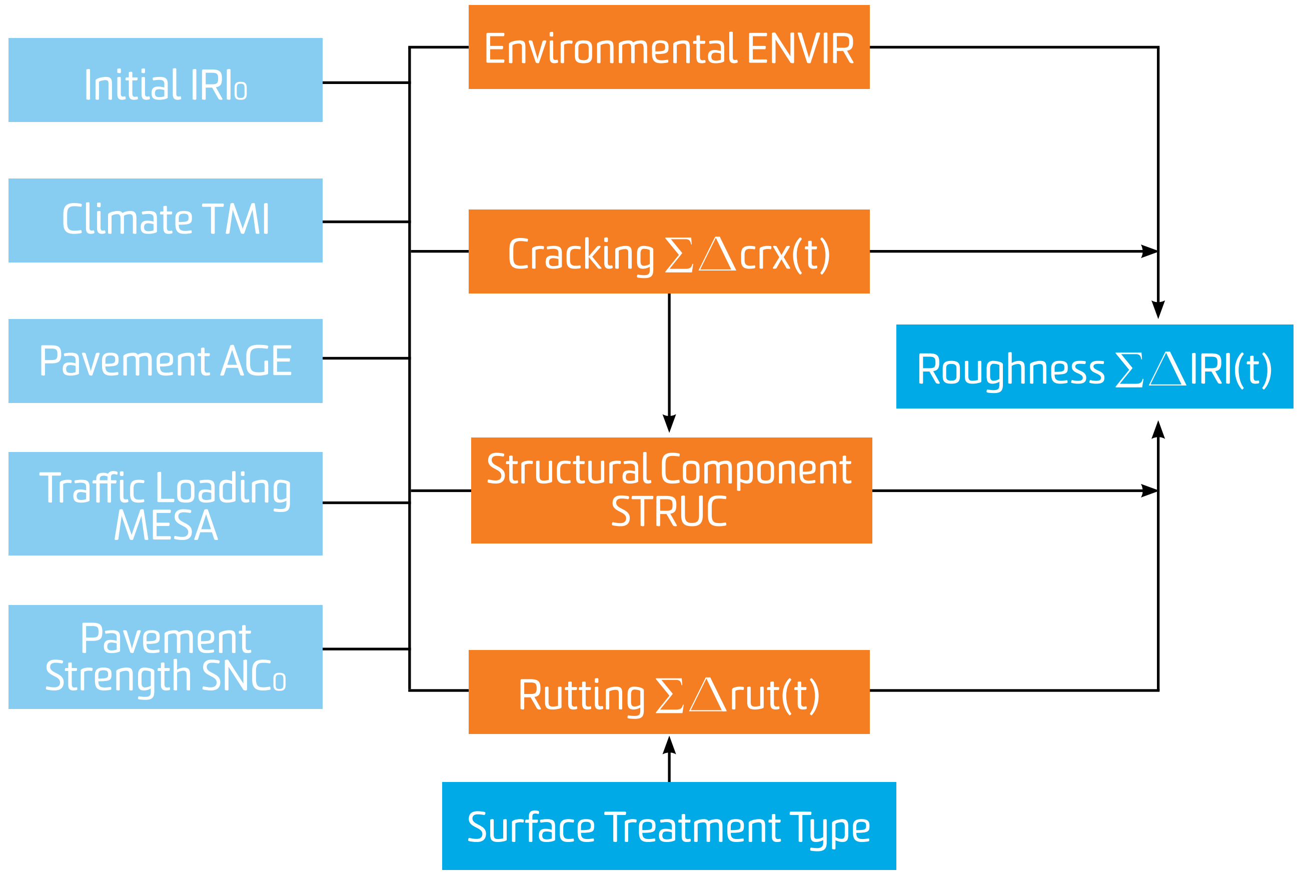

Figure 6 Inter-relationship of the existing functional RD models

FURTHER REFINEMENTS

- As part of a current Austroads Project, the RD models will be upgraded by including the last 10 years of observational LTPP/LTPPM data and sourcing additional LTPP data from the road agencies, including the LTPP data from New Zealand. This aim of this additional data is to increase the number and types of independent variables to increase the explanatory power and robustness of the models.
- The increased interaction of the independent variables ideally should be addressed in the RD model upgrade, although the link between changes in strength and changes in rutting and roughness can involve a considerable time lag which may not be statistically tractable. This project allows the opportunity to test the feasibility of modelling this possible link.
- The development of an improved RD structural model faces challenges in gaining sufficient and reliable local environmental data across the broad spectrum of conditions in both Australia and New Zealand.

SUMMARY

- The long-term pavement performance (LTPP) observational study conducted from 1994 to 2018, in conjunction with the accelerated loading facility (ALF) experimental data, has developed robust deterministic mechanistic-empirical road deterioration models for the gradual deterioration phase for flexible pavement arterial roads in Australia.
- The RD models for rutting and roughness have statistically significant explanatory variables that cover potential changes in traffic load, climate and surface maintenance treatments. These models, along with the cracking and structural deterioration models are being adapted, by means of local calibration and adjustments, to PMSs operated by state road agencies for their arterial road networks. The local calibration can account for local conditions of pavement drainage and soil moisture as well as the reactive nature of some soils.
- A recent upgrade of the rutting and roughness RD models, using relative performance factors for surface maintenance treatments, accounts for the discrete impact of different surface maintenance treatments on the rate of deterioration. This has improved the utility of the RD models that no longer rely on an estimate of the average annual surface maintenance expenditure ($/lane-km) variable, me, based on the year 2000 costs.
- As noted, the RD models will be further refined by 2022 with additional LTPP observational data from Australia and New Zealand.

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RESEARCH GOVERNANCE: PRIORITISING KNOWLEDGE GAPS IN TRANSPORTATION IN AUSTRALIA AND NEW ZEALAND

The transportation field has many touchpoints across a range of disciplines, many of which are interdependent. The gaps in our knowledge needed to optimise our transport system are manyfold. The speed with which the context in which transport is needed can vary too – e.g. a global pandemic - creating different gaps, and sometimes rendering existing knowledge gaps moot.

All of this makes allocation of resources to closing knowledge gaps a difficult and dynamic process. In 2018, ARRB published a National Transport Research Plan (NTRP), outlining suggested knowledge gaps. A founding principle of that plan was that the priorities would change and needed annual review.

By 2019, it was time to check that those were still priorities, with a view to creating an updated NTRP in 2020. This was ultimately scuppered by the advent of the global pandemic, but not before ARRB had done some preliminary work on identifying the industry's view of priorities.

AUTHOR

Dr Mike Shackleton

METHOD

From a scan of industry writing and discussions with colleagues a list of 25 potential priorities were identified with a view to conducting a rating style survey. Upon the advice of professionals who design such surveys, the 25 priorities were reduced to 12. All 25 gaps are listed at the end of this paper; the first 12 are those that were selected for the survey.

A poll was conducted amongst professionals who all had an interest in improvement of transport outcomes through research. 40 responses in total were received, and beyond the above qualification – having an interest in the area – biases in the sample were not evaluated. The intention was to test the level of support for the selected gaps being regarded as important, before a broader engagement program.

To help those being polled, we defined 'knowledge gap' as below:

A knowledge gap is the absence of a piece of knowledge and related implementable research outcomes which is significantly impairing* the ability to achieve necessary connectivity outcomes.**

* Significantly impairing - requiring the use of assumptions and work arounds that cannot be tested or validated, and for which there are no known, better alternatives

** Necessary connectivity outcomes - outcomes of a scale, impact and importance that the public, and or responsible agencies are vociferous about when not delivered or demonstrably care about

Such a gap is of a scale that cannot be solved in a single, limited or short-term enquiry, requiring instead a set of related enquiries or programs (work packages) each delivering a contribution to closing the gap. It is also of a nature that includes the necessity of not only finding knowledge but ensuring that implementable outcomes are developed and implemented.

Respondents asked to rate the 12 problem statements as 'Highest priority' or 'Important' or 'Neutral' or 'lowest priority'. Respondents were able to pick more than one statement for each category.

RESULTS

Using just the 'highest priority' vote from each respondent, the following six emerged as the highest priorities:

Factor (see table of statements for full description of knowledge gap)	% of respondents rating this as one of the highest priorities
Environmental Performance requirements & measurement	48%
Improving quality and durability of infrastructure	46%
Recycled materials in pavements and road & rail infrastructure	38%
Non-construction capacity enhancements for passenger rail	36%
Safe System requirements for active travel	35%
Societal performance requirements for a current & CASE (connected, autonomous, shared and electrified) future	15%

A further analysis was done assessing those factors which were rated either one of the highest priorities or important. The results are shown below:

Factor (see table of statements for full description of knowledge gap)	% of respondents rating this as one of the highest priorities or important
Safe System requirements for active travel	78%
Non-construction capacity enhancements for on-road mass-transit operations	78%
Environmental Performance require-ments & measurement	74%
Societal performance requirements for a current & CASE future	74%
Non-construction capacity enhancements for passenger rail	72%
Inter-modal infrastructure for a CASE future	72%

CONCLUSIONS

Items on both lists are those with both a broadly perceived importance, as well as having a significant core of support as being of the highest importance. Those appearing on both lists were:

- Environmental Performance requirements & measurement
- Non-construction capacity enhancements for passenger rail
- Safe System requirements for active travel

Societal performance requirements for a current & CASE future

Items on the first list but not the second derive much of their support from those who regard them as being of the highest priority, but not having much recognition beyond those supporters. Items in this category are

- Needing to improve the durability of infrastructure and
- The need to use recycled materials in infrastructure.

Items on the second list but not the first are those with a low recognition as a high priority, but a very strong recognition as being important. Items falling into this category were

- Non-construction enhancement of on-road mass transit capacity, and
- The need for better intermodal infrastructure in a connected, autonomous, shared and electrified future.

YOUR VIEWS

As stated, the above reflects a preliminary study in late 2019 as to knowledge gap priorities. In order to help is update this work and complete it with broad input, we'd like your views on the following:

- Were there any gaps on the list of 25 which you would have included in the 'shortlist' of 12 that were not so included?
- If so, which shortlisted items would you have dropped off the list of 12 to accommodate it?
- How does your rating of the shortlisted 12 gaps line up with those presented?

What important items were left off the list of 25?

Send the author a message with your suggestions, or leave your contact details for a follow-up conversation.

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25 PRIORITY RESEARCH GAPS IDENTIFIED IN LATE 2019

1. Transitioning surface transport to a Connected, Autonomous, Shared, Electrified (CASE) future
We know what the current situation is, we can envision the future, but what are the barriers to transition in the midst of a function transportation system?

2. Inter-modal infrastructure for a CASE future
As the number of modes increases so too do the combinations of operations and modal interchanges for both passengers and freight; the challenge is to avoid duplication and avoid creating unsafe and inefficient operations. How?

3. Societal performance requirements for a current & CASE future
To enable society-centric systems we must understand and take cognisance of societal requirements of our transportation systems. What are these requirements and how should they be measured/tracked?

4. Environmental Performance requirements & measurement
To enable transport systems that progressively reduce their negative impact on the environment, we must take cognisance of both positive and negative impacts; what are they and how do we measure/track them?

5. Framing and enabling safe, agile adoption of new modes and micro-modes
The private sector is quick to develop new modes and micro-modes to help mobility (and provide a profit). How these should be evaluated prior to adoption/approval to ensure safe implementation without undue delay is uncertain and a bone of contention.

6. Understanding, planning for and enabling the modern 'commuter trip' and micro-freight
The language used in the profession still harkens back to the days when a commuter trip meant to-work-and-back (8:30 to 5:00) and freight did not include micro-freight and supermarket deliveries. A system reset requires a mindset reset.

7. Safe System requirements for active travel
Active travel – walking, cycling, running – is an environmentally friendly mode (for travellers and micro-freight) which is hampered to a great extent by safety perceptions, including inter-modal conflicts. How can safe system principles overcome this?

8. Non-construction capacity enhancements for passenger rail
Australia's rail network represents significant asset, which operates sub-optimally. "Building more capacity" is an expensive and slow means of improving service levels. What can be done from a control and operational perspective to improve suburban rail performance, particularly?

9. Non-construction capacity enhancements for on-road mass-transit operations
The majority of public transport trips take place in on-road modes. Building more road space to improve publi transport is not a sustainable or feasible response. What can be done from an operations/ priority/rollingstock perspective to increase capacity?

10. Defining/Measuring capacity and usage of new modes, active transport
As new modes and micro-modes make their appearance, how can we estimate, predict and track the capacity they offer, and the extent to which that capacity is used?

11. Recycled materials in pavements and road & rail infrastructure
Asphalt has been recycled for 40 years. Recycled crushed glass and crumbed rubber have been successfully used in road infrastructure. What other opportunities exist, what are the limits of their application and the barriers to their use?

12. Improving quality and durability of infrastructure
Construction quality determines future performance and cost of infrastructure. Increasingly, evidence of poor construction is emerging – not restricted to road infrastructure. How can we simply ensure that infrastructure is built the way it is supposed to be built?

13. Economic performance measures and requirements
A CASE future comprises in part a reset of the economy. What are the new or emerging economic performance benchmarks, and how do we measure and track them?

14. Worker-free road and rail reserves
Maintenance workers, construction workers, first responders and law enforcement all have the road reserve as their workplace from time to time. As a workplace, what can we do better to ensure the safety of these workers?

15. Value Capture and other financing innovations for a CASE Transport future
If a case future represents a reset of society and the economy, what opportunities exist to reset the economics and finances of transportation?

16. Other roles for road surfaces; roads as multi-function devices
Road surfaces are dumb acreage, existing as a flattish, hard surface upon which to travel. As an industry, we can improve the RoI that infrastructure provides through increasing the number of functions it performs; what are those functions?

17. CASE opportunities for Travel demand management
The best trip for congestion is one not made; in a CASE future what opportunities exist to create more of these 'perfect' trips?

18. Closing the city vs everywhere else connectivity divide
Australians have an as-of-right access to publicly own transport systems. Sometimes, those systems for some Australians are non-existent ('the wet') or so poor that they impact on quality of life (outer suburbs). What options exist for closing the divide?

19. Transitioning to Mode-agnostic mobility/ Mobility as a service
What are the barriers and appropriate countermeasures that will allow commuters/ passengers/freight companies to embrace the most efficient means of moving, regardless of the modes involved?

20. Understanding changes in decision-making regarding modal attractiveness
Transport systems and modes must fulfil user needs – be they students or freight companies. System success is therefore predicated on understanding these needs, how and why they change and whether or not changes are predictable.

21. Configurable fit-for-purpose road spaces
Infrastructure has typically had long design lives, locking the configuration of valuable road space in place, potentially beyond the point of usefulness. What can be done to make the road space and its configuration more adaptable and fit-for-best-use over its lifetime?

22. Exploiting unutilised infrastructure capacity
Demand for infrastructure capacity is not constant. What opportunities exist, and what are the barriers to be overcome, in exploiting capacity which is not currently in use?

23. Disruption-free maintenance for road and rail infrastructure
Infrastructure needs maintenance to maintain safety and levels of service. Such maintenance disrupts its ability to provide that service. What materials, construction and monitoring technologies exist to minimise or eradicate the need for hugely disruptive maintenance operations?

24. SEE (Societal, Environmental, Economic) management of infrastructure
Since the 1960s and 70s, infrastructure has been maintained on the basis of economics; minimising whole-of life costs, total transport costs etc. How can dollars compete with the non-negotiables of safety and sustainability in our reckoning?

25. Self-reporting/diagnosing infrastructure
Just-in-time intervention is a means of optimising expenditure. What technologies exist to help bring this about through having infrastructure report unexpected levels of stress, strain, load etc?

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