NACOE
NATIONAL ASSET CENTRE OF EXCELLENCE

ANNUAL HIGHLIGHTS REPORT
2020 – 2021

AN INITIATIVE BY: arrb | Queensland Government

CONTENTS

FOREWORD BY NACOE BOARD

Welcome to the 2020-2021 Annual Highlights Report for the National Asset Centre of Excellence (NACOE). This report is an opportunity to reflect upon the continued collaborative research agreement between the Queensland Department of Transport and Main Roads (TMR) and the Australian Road Research Board (ARRB) over the past eight years to enhance the safety, efficiency, and sustainability of Queensland's critical infrastructure. Our research partnership was reaffirmed this year, with the signing of a new 2021-2026 agreement that will continue to advance our use of combined best resources to provide practical solutions to today's transportation challenges (read more on pg. 10).

It is pleasing to see that during this challenging year as a result of the Covid-19 pandemic impacts, our research has continued to build on the incorporation of best practice frameworks, promoting new knowledge sharing and exploring innovative practices across Queensland and beyond. This year's research highlights include some significant strides in advancing our understanding of new technologies and engineering tools and, the opportunities of data analytics for use in long-term asset performance monitoring.

A key focus for NACOE is to embrace demonstrations of the latest modern innovative practices, materials, and technologies toward improving efficiency and best practice outcomes for Queensland transport infrastructure design, construction operation and management. The research has benefited from working with some incredible industry and delivery partners throughout the year including:

» Partnered with the Queensland University of Technology and Logan City Council to trial Intelligent Compaction (IC) technology on the Logan City Council Street Pavement Rehabilitation Project (read more about the recognition this collaboration received on pg. 11)

» Investigated the viability of using alternative testing techniques to control the quality of compaction during the construction of earthworks (read more about the developments of this five-year study on pg. 20)

» Increased understanding of Intelligent Construction (IC) practices through multiple industry engagements and knowledge sharing activities (read more about the detailed future roadmap for IC on pg. 22)

» Investigated Machine Learning Modelling and Artificial Intelligence (AI) as a tool for Project and Program Managers to validate traditional project cost and duration forecasts (read more about the promising AI observations on pg. 24)

» Developed a prototype tracking tool to better inform access and asset management decisions for Class 1 heavy vehicles (read more about the progress of data analytics on pg. 42).

Looking to the future, we will continue to work with our stakeholders and delivery partners to implement research outcomes, share knowledge nationally and drive savings that benefit the Queensland community and beyond. We acknowledge and thank our people and industry partners who have played a key role in delivering these beneficial outcomes, and we hope you enjoy reading the rest of the highlights featured in this report.

Amanda Yeates
Chair (TMR)

Dennis Walsh
TMR

Matthew Bereni
ARRB

Richard Yeo
ARRB

OUR MISSION

Since 2013, NACOE has driven savings and enhanced national technical capability in transport and road asset engineering through:

UNLOCKING INNOVATION
IMPLEMENTING INTERNATIONAL BEST PRACTICE
TRANSLATING NEW KNOWLEDGE INTO PRACTICE

STRATEGIC OBJECTIVES

DEVELOPMENT

Developing the capabilities of staff and disseminating learnings to TMR regions and industry.

COST SAVINGS

Delivering economic benefits to the Queensland network through cost-effective innovation and higher performing pavements, refined asset management practices, efficient management of structures and optimising road safety and network operation outcomes.

COLLABORATION

Working in partnership with industry, universities, and government bodies to leverage research and resources, helping to deliver mutually beneficial outcomes.

IMPLEMENTATION

Facilitating demonstration projects, establishing research tools and infrastructure to help implement new technologies and practices in Queensland.

ACKNOWLEDGEMENT

We would like to acknowledge our partners, the Queensland Department of Transport and Main Roads (TMR) and the Australian Road Research Board (ARRB) for their collaboration on the development of the NACOE Program over the past eight years.

We would also like to thank and acknowledge the organisations, universities, delivery partners and industry associations who collaborated on NACOE projects, of whom without their valued support and input, much of the road research work we do, would not be possible.

ABOUT OUR PARTNERS:

Queensland Department of Transport and Main Roads (TMR)

The Department of Transport and Main Roads (TMR) moves and connects people, places, goods, and services safely, efficiently, and effectively across Queensland. They plan, manage, and deliver Queensland's integrated transport environment to achieve sustainable transport solutions for road, rail, air, and sea.

TMR's vision is to create a single integrated transport network accessible to everyone. The integrated transport planning approach ensures TMR contributes to people's quality of life, Queensland's economic wellbeing, and a sustainable environment.

Australian Road Research Board (ARRB)

ARRB was founded in 1960 and is the source of independent expert transport knowledge, advising key decision makers on our nation's most important challenges. ARRB has a strong heritage of supporting and delivering high quality applied research for Australian and New Zealand state road agency members and for the community. ARRB's vision is to help make the world's cities smarter, cleaner, greener, safer, more efficient, and productive through intelligent transport solutions.

BENEFITS OF NACOE

NACOE is continuing to deliver strong economic and sustainability benefits to TMR and the broader Queensland community. The program has delivered many high value research projects since its inception. Some of the key benefits of NACOE to date include:

- progressing our investigation into Intelligent Compaction and its potential role in future road construction
- increasing the use of recycled tyres in our pavements
- delivering a pilot specification for Crumb Rubber Modified Open Graded and Gap Graded Asphalt
- reducing in the thickness of heavy-duty asphalt pavements that has led to savings in construction costs, construction time and material, resulting in sustainability benefits to the community
- increasing environmental benefits through the increased use of recycled vehicle tyres in sprayed seals and asphalt
- leading the way in the use of high percentages of recycled asphalt pavements
- reducing ongoing agency costs resulting in improved whole-of-life transport solutions
- improving asset management practices that have resulted in reduced agency and road user costs
- improving risk management practices for the planning, design, and maintenance of transport infrastructure
- improving understanding of the behaviour of bridges under live traffic loading, resulting in possible cost savings due to the deferment of strengthening or replacement projects
- increasing confidence to use higher percentages of recycled materials in TMR's pavement specifications
- guidance toward reducing crash risks on Queensland roads.

NACOE research continued to prioritise funding to projects with clear benefits for Queensland.

AWARDS AND ACHIEVEMENTS

NACOE CONTINUES TO LEAD THE WAY IN DELIVERING ENGINEERING EXCELLENCE IN QUEENSLAND

Queensland's Department of Transport and Main Roads (TMR) and the Australian Road Research Board (ARRB) reaffirmed their commitment to NACOE, through the signing of their renewed agreement for 2021-2026.

The new agreement was signed on the 3rd of September 2020 by Queensland's Department of Transport and Main Roads Director-General Neil Scales OBE and ARRB's Queensland State Technical Leader Matthew Bereni. Through NACOE, TMR and ARRB continue to combine resources to optimise innovation to provide smarter engineering outcomes to both the Queensland and the Australian road industries.

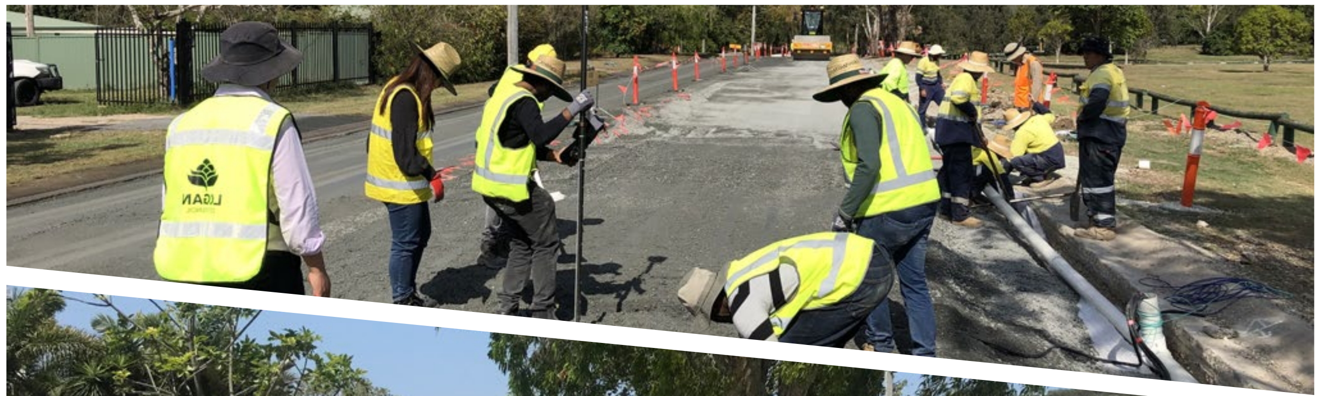
The Program has been a leading force to expanding the range of products and approaches that can be included in standards and specifications toward increased uptake by industry. As part of this, NACOE is heavily focused on collaborating with industry to improve best practices by bringing new knowledge into practise sooner and providing efficiency gains on a national scale.

NACOE AND LOGAN CITY COUNCIL WINS EXCELLENCE AWARD IN COLLABORATION

In collaboration with the Logan City Council (LCC) and the Queensland University of Technology (QUT), NACOE assisted with implementing Intelligent Compaction (IC) technology on the Logan City Council Street Pavement Rehabilitation Project completed in November 2019, which won the Local Government Managers Australia Queensland (LGMAQ) Excellence Award 2020 in the Collaboration category.

It was the first of its kind in Australia to capture data that allows council to manage unstable ground in a more efficient way.

The project utilised IC technology which allows the roller operator to gain real-time feedback to test compaction quality and adjust as they go. This results in ongoing asset management savings through identifying roads which are at early risk of failure before costly problems arise, while building better roads for Queenslanders. The collaboration has strengthened the opportunity for local governments to play a leading role in cutting-edge road research and the development of innovative technologies.



CAPABILITY DEVELOPMENT

The NACOE program has supported several important capability development initiatives and knowledge transfer activities, including:

- workshops that provided enhanced understanding of the performance of Queensland's sprayed seal network
- developed technical guidance and fact sheets to assist practitioners with the application of suitable countermeasures on narrow sealed roads
- delivered several IC knowledge sharing presentations and initiatives including a roadmap plan for industry stakeholders to:
  - define different phases for the use of IC to assist with future forecasting and ensuring the necessary equipment, software packages, trained personnel, and resources for successful on-site IC project implementation
  - demonstrate the benefits of IC technology using a benefit-cost analysis (BCA) for road authorities to consider the bigger picture and whole life cycle costs
- provided knowledge sharing of practical findings from the IC field trials including training videos for the ease of use of Veta 7.0 package for IC data display and analysis
- developed guidance and tools to support a comprehensive, risk-based framework to help assist in funding allocations of different asset elements
- developed a new Technical Note: Managing Dispersive and Slaking Soils on Infrastructure Projects
- Developed a new EME2-specific design relationship capturing the unique performance benefits of EME2, which has been included in TMR's Pavement Design Supplement
- 20 reports, presentations, and papers from 2020/2021 were published and are available on the NACOE website
- 4 online webinars were published on the NACOE website.

NACOE RESEARCH PROGRAM IMPLEMENTATION

The outputs of the NACOE research program were implemented through:

- the development of technical notes and design guide improvements
- the development of new technical specifications
- implementation through demonstration projects
- the dissemination of learnings through presentations, seminars, and webinars
- the preparation and presentation of technical papers and industry events
- validating existing practice through data gathering and analysis.

TMR is a member of Austroads, which undertakes research to develop nationally consistent guidelines. The work of NACOE and Austroads is often complementary to each other, whereby NACOE research further develops the Austroads findings to ensure that Queensland conditions and materials are fully considered and implemented. In many instances, the outputs from NACOE research have been fed through the various Austroads task forces and working groups, which then filter into national documents.

Research is delivered using a range of strategic research methodologies, including:

- Desktop reviews to better understand the research need, benefits, or application prior to progressing with a more in-depth study.
- Where there is confidence in achieving a positive result, a follow-on project is often initiated that may include laboratory testing and field trials.

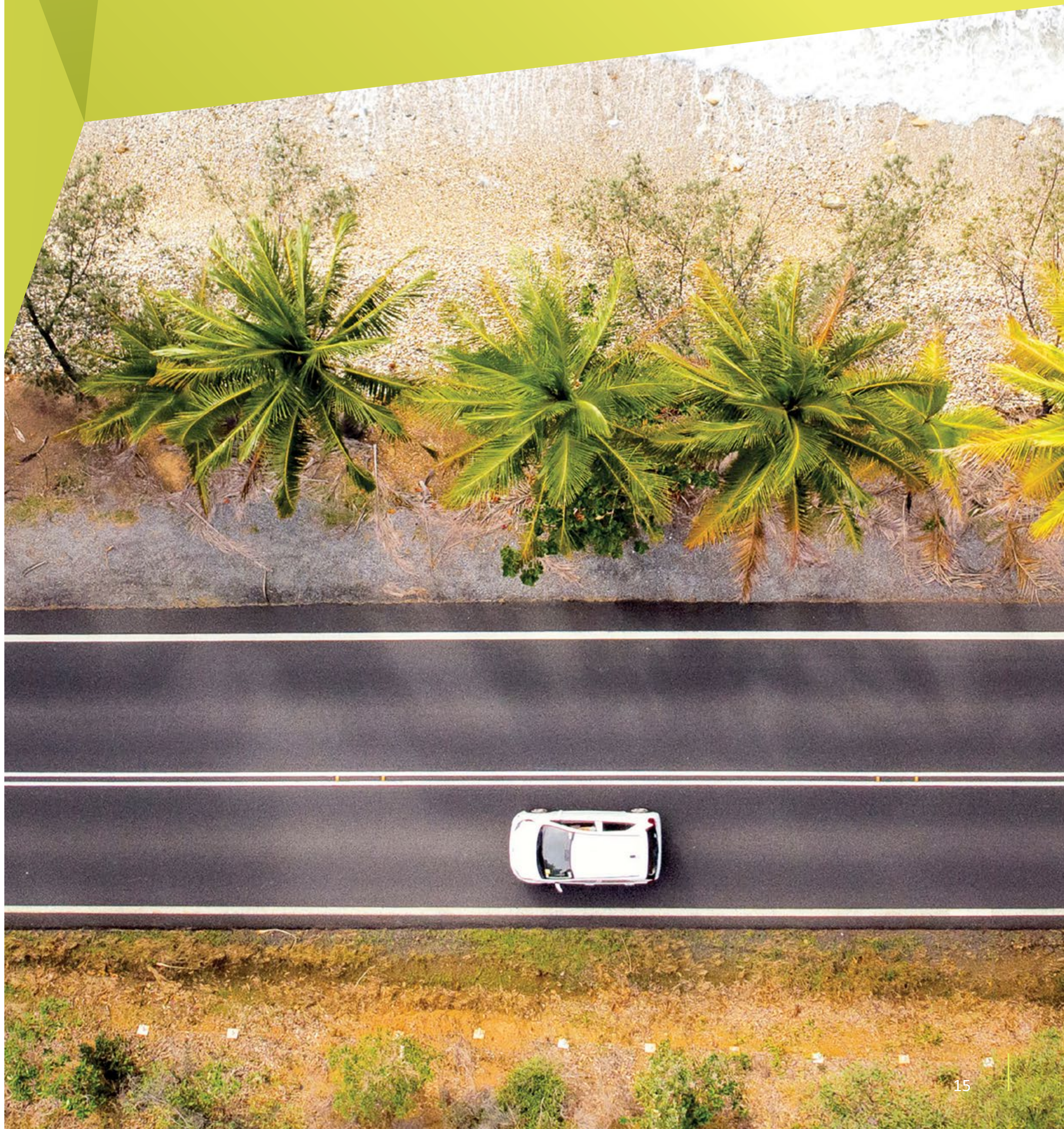
COLLABORATION AND DISSEMINATION OF LEARNINGS

A key strategic objective of NACOE is to facilitate ongoing development through the dissemination of learnings to industry and the regions as well as collaboration with industry, universities, and government bodies. The NACOE Board believes ongoing collaboration will allow TMR to leverage off research and resources from other organisations, which in turn will deliver mutually beneficial outcomes to everyone involved.

NACOE has worked with multiple external organisations, including:

- The Queensland Department of Environment and Science – to develop technical guidelines and specifications for the use of recycled tyres and glass
- Local Government Association of Queensland – to develop Local Government Heavy Vehicle Route Assessment Guidelines
- Central Queensland University – to investigate an objective, automated method, and software for identifying roadside objects and road design features for road safety assessment
- The Queensland University of Technology – to quantify the benefit of geosynthetics for the mechanical stabilisation of subgrade materials and develop guidelines for pavement design
- The Western Australia Road Research and Innovation Program (WARRIP) on multiple collaborative research projects
- Tyre Stewardship Australia – facilitating the use of recycled tyres in Queensland
- Logan City Council – investigating the benefits of subgrade reinforcement using geosynthetic layers and the implementation of Intelligent Compaction (IC)
- City of Gold Coast – implementation of crumb rubber modified gap graded asphalt
- Australian Flexible Pavement Association (AfPA) – the implementation of Intelligent Compaction technology into Queensland, as well as the development of a new specification for crumb rubber modified gap graded asphalt
- The Transtec Group Inc. – collaboration on the Veta 7.0 training for Intelligent Compaction Data Management (ICDM).

These collaborations are pivotal to the success of the NACOE research program and will continue in future years.



01

PAVEMENTS

PAVEMENTS

The Pavements stream represents the largest proportion of the NACOE program, with a significant number of projects and approximately half the total investment. This program is focused on introducing innovation and delivering engineering best practice across several areas including but not limited to:

» asphalt

» road surfacing's

» unbound granular, recycled material blends and marginal materials

» stabilised/modified pavements

» several sustainability and innovative technology projects (including alternatives to traditional pavement materials).

The findings from this research have the potential to deliver significant cost savings to Queensland and the wider Australian community and create more opportunities for further road projects to be constructed.

The major outcomes to date from the NACOE pavements program include:

» informing TMR's specifications to enable reduced depth of asphalt structural layers through the adoption of EME (Enrobé à Module Élevé) high modulus pavement

» informing TMR's design procedures to enable refinement of pavement thickness design based on improved asphalt pavement design procedures

» facilitating the use of asphalt mixes including recycled content (crumb rubber modified binders and recycled crushed glass aggregates)

» improved understanding of using non-standard and/or marginal granular materials through performance validation and evaluation guidelines. These pavements are widely used in western Queensland, due to unavailability of conforming materials. While they offer significant savings, they can involve increased risk of poor performance, so these risks need to be understood and managed

» Increased knowledge to inform upgrading specifications, based on the review of world's best practice, and laboratory research

» streamlined use of recycled material and recycled material blends for unbound granular pavement layers

» knowledge toward increased use of recycled materials in bituminous products across the network, to deliver environmental benefits and enhanced sustainability.

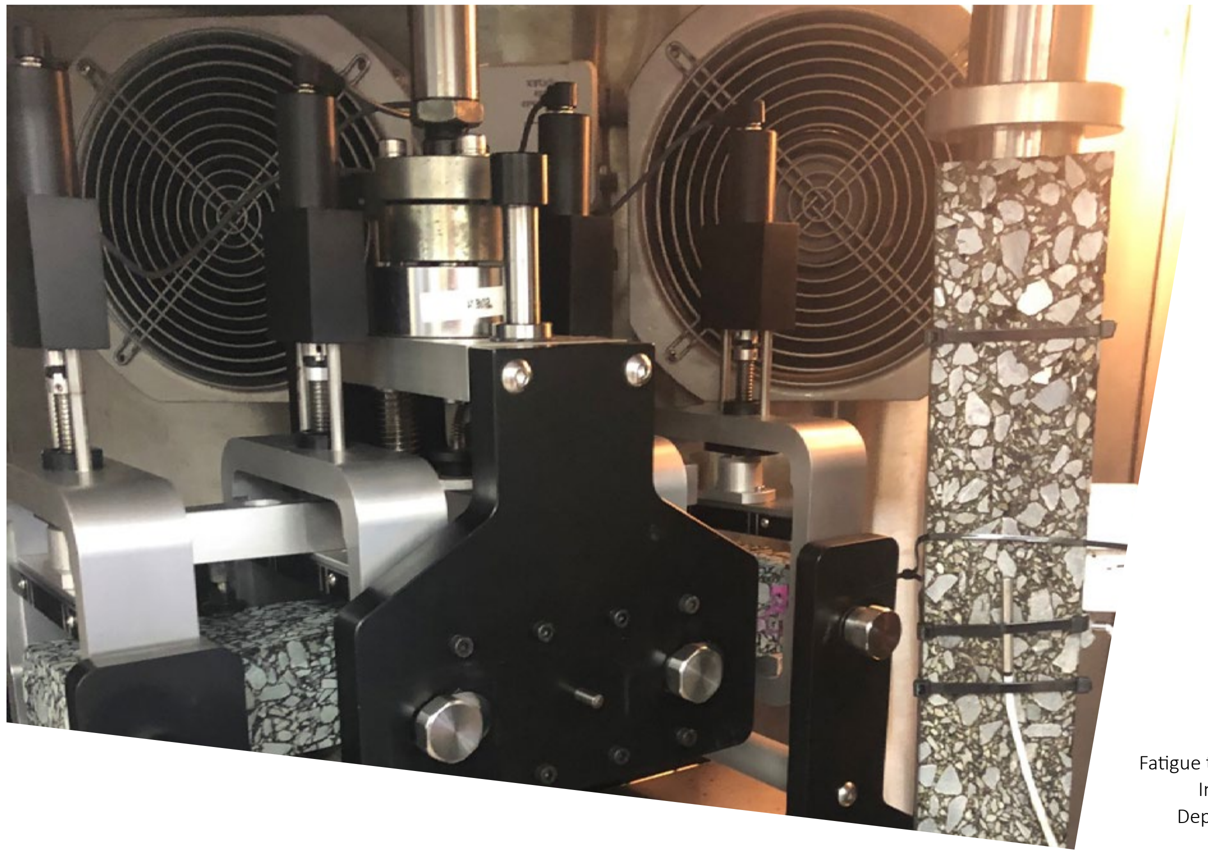
The program also has a strong focus to collaborate with industry and universities.

COST EFFECTIVE DESIGN OF ASPHALT PAVEMENTS AT QUEENSLAND PAVEMENT TEMPERATURES

As part of its ongoing commitment to developing sustainable and fit-for purposes pavement structures for Queensland conditions, NACOE previously developed technical guidelines and specifications to facilitate the implementation of high performance Enrobés à Module Elevé Class 2 (EME2) asphalt.

Originally, the thickness design of EME2 layers was based on the presumptive fatigue relationship recommended by Austroads for all mix types. This relationship was developed over 40 years ago based on testing a limited number of international asphalt mixes. It was therefore unclear if the Austroads relationship is still applicable to modern mixes being used in Queensland, including EME2.

NACOE Project P10: Cost Effective Design of Asphalt Pavements at Queensland Pavement Temperatures undertook a multi-year study to assess the modulus and fatigue performance of locally manufactured EME2 mixes in the laboratory. The project identified an opportunity to replace the generic Austroads fatigue relationship with a new EME2-specific relationship that can be used for pavement designs in Queensland. The new relationship captures the unique performance benefits of EME2 (i.e., high modulus values in conjunction with improved fatigue resistance) and has subsequently been included in TMR's Pavement Design Supplement.



Fatigue testing at TMR laboratory. Image Source: Queensland Department of Transport and Main Roads (TMR)

NACOE

BEST PRACTICE IN COMPACTION QUALITY ASSURANCE FOR PAVEMENT AND SUBGRADE MATERIALS

The current industry practice relies on the use of in-situ dry density ratio (DDR) to control the quality of compaction during the construction of earthworks. The main reason for this is the density measurements are relatively easy to undertake during construction, and the parameter itself is precise with limited variability. However, this approach has two major disadvantages, namely:

» the in-situ modulus of the layers which is the input in pavement design is not directly measured, and

» there is significant delay between the time of undertaking the DDR measurement and the delivery of the final test results to address any issues in a timely manner.

Delay in the provision of test results can lead to increased re-work when earthworks are found to be non-conforming and require remediation after the works have further progressed. This research project investigated the viability of using alternative test methods to address these issues. The five-year study investigated a range of alternative testing devices, such as the light weight deflectometer (LWD), Clegg Hammer and PANDA probe with a focus on evaluating their effectiveness in assessing the quality of the earthworks constructed. A methodology was developed to adopt the LWD as an alternative Quality Assurance (QA) test method. However, the methodology is equally applicable for other similar technologies. The deliverables of the project include:

» A project report presenting the final research outcomes to allow the adoption or trialling of this alternative approach in future roadwork construction projects

» Proposed amendments to MRTS04 General Earthworks

» A technical note that details the technical basis and approach

» Several webinars have also been presented to disseminate the findings and seek industry feedback.

Equipment evaluated in Year Two of the project.
Image Source: Lee et al. (2019)

THE USE OF RECYCLED GLASS IN PAVEMENTS

In 2018, a multi-year project began with the aim of facilitating the use of recycled crushed glass (RCG) in pavement applications, including asphalt layers.

The literature review undertaken during the first year of the project indicated that RCG may be incorporated into asphalt without detrimentally impacting performance. It was found that up to five percent RCG could be successfully incorporated into a typical TMR dense-graded asphalt (DGA) mix based on the limited testing undertaken.

Year Two of the project primarily focused on investigating the laboratory performance of DGA containing up to 10 percent RCG by mass of the total mix. Additionally, an evaluation of the variability of RCG sourced from several suppliers in Queensland was undertaken to facilitate the development of a new specification for RCG and the updating of current TMR specifications.

The third year of the project in 2020-21 focussed on assessing the outcomes of a demonstration project that incorporated five percent RCG in the asphalt surfacing course and reviewing the performance of several existing roads where RCG was previously used in the surfacing course. Laboratory testing did not identify any risks associated with increased permanent deformation or moisture damage due to the addition of five percent RCG in the asphalt mix.

A visual inspection of a selection of roads with RCG in the surfacing course (ranging in service life between one and 10 years) was also conducted. There was no evidence of accelerated deterioration of the asphalt mixes with five percent RCG. Subsequently, the Department (TMR) published a new technical specification for recycled glass aggregates and updated its asphalt specification to allow up to 2.5% in surfacing layers and 10 percent RCG in all other layers.

A hand holding crushed glass at a recycling facility.
Image Source: Central Recycling Services

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INTELLIGENT COMPACTION - ASSESSMENT OF THE BENEFITS AND LIMITATIONS FOR QA IN ROAD CONSTRUCTION

Compaction is critical for the performance of all pavement layers and impacts a road's life and the total costs of maintaining it at an acceptable or desirable level over its service life. Intelligent Compaction (IC) is a proven technology that has gained popularity around the world and has been shown to improve construction quality and productivity in the last 15 years.

The first year of the project focused on a comprehensive literature review to evaluate the potential benefits of such technology for the Queensland Department of Transport and Main Roads (TMR) and the wider road construction industry. In the second year, a pilot project-specific technical specification (PSTS116) was developed to trial different materials on the Ipswich Motorway Upgrade project (stage 1, Rocklea to Darra). The materials compacted by IC included embankment fill, subgrade, cement modified base, and unbound granular base. These trials demonstrated that IC technology can readily identify soft areas in a pavement or embankment and can be used to improve the uniformity of the compacted layers. The study showed that the Compaction Meter Value (CMV) has varying degrees of correlation against the in-situ stiffness measured by a light weight deflectometer (LWD) and conventional density results (measured by a nuclear density gauge), noting that the CMV is sensitive to in situ moisture conditions during construction.

The project funded Veta 6.0, the IC data management software package, to support the latest GDA2020 system which became the main cadastral grid to be used across different jurisdictions in Australia. At this stage, it was identified that there will be significant learning required for the industry to become familiar with IC technology and to incorporate it into construction practices.

Online webinars were delivered to industry to disseminate the results from the demonstration trial (webinars, as well as virtual masterclass and training on Veta, held in collaboration with the Australian Flexible Pavement Association).

The focus in 2020-21 was to disseminate knowledge and local experience on IC technology and promote its many benefits. The team monitored the demonstration field trials as well as started planning for future trials using other materials. Different levels of trainings were also developed to share the knowledge and practical findings from the field trials, as well as training videos for the use of Veta 7.0 package to ease its use for data display and analysis.

A business case was developed using benefit-cost analysis (BCA) covering the financial and environmental impact of using IC from both the client and contractor's perspective. It demonstrated that even on the conservative side, using IC is beneficial for road authorities when considering the big picture and whole of life cycle costs.

To help support the uptake of IC within the industry, a high-level implementation plan was introduced to stakeholders to define different phases via a road map for use of IC in future projects. The road map will help with future forecasting and ensure the industry has the necessary equipment, software packages, trained personnel and resources for successful IC project implementation on-site.

The trials and practices conducted provided an opportunity to understand the requirements and details of how road agencies can monitor, oversee, quality control and accept road work using IC technology. This includes relevant specifications, technical standards, comprehensive contracts, and operational requirements. The next stages of the project will focus on providing a technical guide for the use of IC technology.

Intelligent Compaction fieldwork demonstration in Queensland.
Image Source: NACOE (2020)

NACOE

EXPLORING THE USE OF ARTIFICIAL INTELLIGENCE (AI) SOLUTIONS TO IMPROVE THE ACCURACY OF PROJECT DELIVERY FORECASTS

Machine learning (ML) models use ample amounts of high-quality project data to identify predictive patterns in large datasets that have minimal missing values. TMR has a significant amount of infrastructure project delivery data; improving the predictability of project cost, duration and under/overruns is a challenging problem that affects major projects. Artificial intelligence (AI) technologies such as machine learning models offer a faster, cheaper, and more powerful way to build evidence-based predictive models for tackling these challenges.

This project investigated the suitability and performance of AI solutions to enhance decision-making of project cost and duration forecasting (through improved accuracy and precision). With appropriate instructions, suitable data and calibration, ML models provide improved final cost forecasting accuracy that may assist TMR's budgeting capabilities for individual projects and their works program.

The project scope entailed an evaluation of the suitability of TMR project data for use in ML models as well as the effectiveness and accuracy of ML models in predicting the forecast final costs and forecast completion dates of projects using provided datasets. Predictive analytics were carried out on TMR's dataset, which presented evidence-based predictive and descriptive observations. Machine learning modelling for project cost and duration forecasting was developed and tested, resulting in the following observations:

For individual projects:

- The model improved the final construction costs by reducing the prediction percentage error by 21% (15.9% error for the business versus 12.6% for the model) forecasting an average savings of $148,000.
- The model improved forecasting final construction duration by a reduction in the prediction error by 11% (8.5 days) (26% error for the business versus 23% for the model)
- The model improved the early warning of duration underrun and overrun by an average of four and two months, respectively
- The model improved the early warning of cost underruns by an average of four months.
- For the aggregate portfolio of all projects:
- The model improved the cost forecast predictions by reducing prediction error by 87% (from 10.7% error for the business versus 1.4% for the model)
- The model measured the aggregate portfolio value and tracked the actual value more accurately than the current TMR approach.

Figure C.7: Time to first warning (months) – construction duration underruns

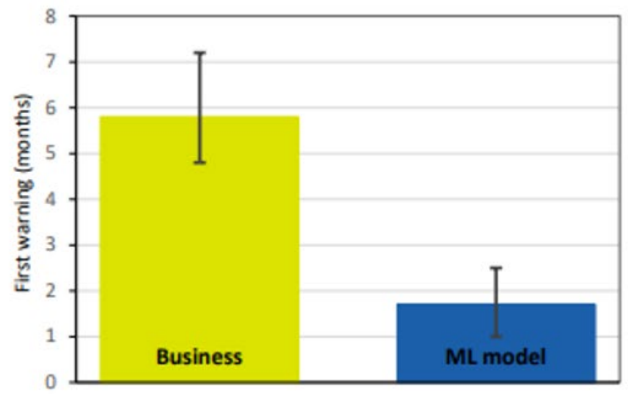
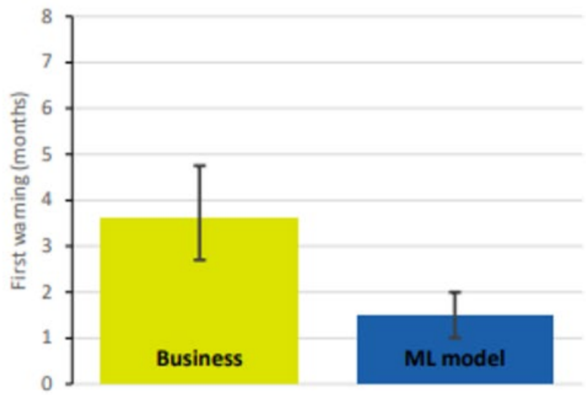


Figure C.8: Time to first warning (months) – construction duration overruns



Final data of construction duration underruns – Time to first warning (months).
Image Source: Stage 3: Modelling Report (Endeavour Programme, 2020d).

TMR's substantial project database has demonstrated applicability for ML modelling to improve the accuracy and precision of project cost and duration forecasting by identifying significant financial and delivery opportunities for re-distributing capital budget and/or contingency back into their portfolio. ML predictions may be a valuable and effective tool for Project and Program Managers to validate traditional cost and duration forecasts.

Overall, AI technologies have demonstrated:

- capabilities that enhance capital productivity
- portfolio performance
- early warning capability, and
- a decrease in monitoring costs.

NACOE

USE OF RECYCLED MATERIALS IN PAVEMENT LAYERS

In Queensland, the uptake of recycled material usage in unbound granular and stabilised pavements has been relatively limited since the 2010 publication of MRTS35 Recycled Materials for Pavements (TMR 2018a). There are various reasons for this, which include:

» the perceived inferiority of recycled materials to that of virgin materials, and

» the barriers in material procurement associated with recycled and natural/quarried materials being specified separately.

The objective of this multi-year project was to identify how the use of recycled materials can be optimised to achieve cost, sustainability, and long-term performance benefits and help facilitate the increased use of recycled materials in unbound pavements for the Queensland Department of Transport and Main Roads (TMR).

Based on the outcomes from previous stages of this project, TMR updated MRTS05 Unbound Pavements to be a single specification for natural, quarried, and recycled materials.

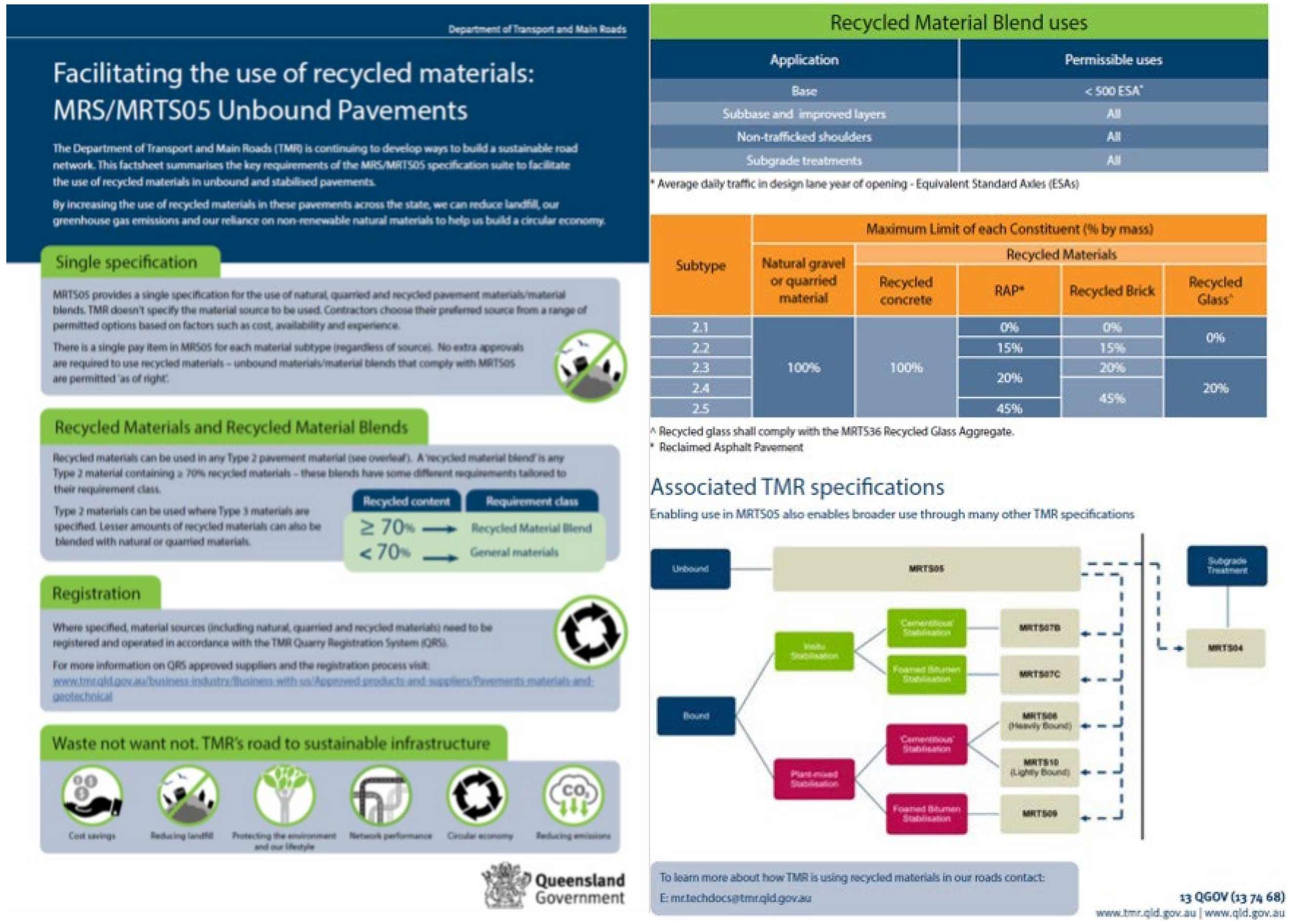
Industry feedback has been positive towards the benefits this has made to increasing the use of recycled materials in unbound pavements.

To communicate the outcomes and specification updates arising from the first two years of the project, the third and final year of the project aimed to undertake several dissemination-of-learnings activities. The project's final outputs are outlined below, alongside the following dissemination activities:

» Webinar – delivery of a webinar to communicate the overall project and resultant specification updates to MRTS05 (TMR 2020) and allow time for a live Q&A interaction with interested parties

» Infographic – development of an infographic/fact sheet describing the changes to MRTS05 (TMR 2020)

» Report – publication of the Year Three report, documenting the key outcomes of the research, and dissemination activities undertaken.



Department of Transport and Main Roads

Facilitating the use of recycled materials: MRS/MRTS05 Unbound Pavements

The Department of Transport and Main Roads (TMR) is continuing to develop ways to build a sustainable road network. This factsheet summarises the key requirements of the MRS/MRTS05 specification suite to facilitate the use of recycled materials in unbound and stabilised pavements.

By increasing the use of recycled materials in these pavements across the state, we can reduce landfill, our greenhouse gas emissions and our reliance on non-renewable natural materials to help us build a circular economy.

Single specification

MRTS05 provides a single specification for the use of natural, quarried and recycled pavement materials/material blends. TMR doesn't specify the material source to be used. Contractors choose their preferred source from a range of permitted options based on factors such as cost, availability and experience.

There is a single pay item in MRS05 for each material subtype (regardless of source). No extra approvals are required to use recycled materials – unbound materials/material blends that comply with MRTS05 are permitted 'as of right'.

Recycled Materials and Recycled Material Blends

Recycled materials can be used in any Type 2 pavement material (see overleaf). A 'recycled material blend' is any Type 2 material containing ≥ 70% recycled materials – these blends have some different requirements tailored to their requirement class.

Type 2 materials can be used where Type 3 materials are specified. Lesser amounts of recycled materials can also be blended with natural or quarried materials.

Recycled content	Requirement class
≥ 70%	Recycled Material Blend
< 70%	General materials

Registration

Where specified, material sources (including natural, quarried and recycled materials) need to be registered and operated in accordance with the TMR Quarry Registration System (QRS).

For more information on QRS approved suppliers and the registration process visit: www.tmr.qld.gov.au/business-industry/Business-with-us/Approved-products-and-suppliers/Pavements-materials-and-geotechnical

Waste not want not. TMR's road to sustainable infrastructure

Cost savings · Reducing landfill · Protecting the environment and our lifestyle · Network performance · Circular economy · Reducing emissions

Recycled Material Blend uses

Application	Permissible uses
Base	< 500 ESA*
Subbase and improved layers	All
Non-trafficked shoulders	All
Subgrade treatments	All

* Average daily traffic in design lane year of opening - Equivalent Standard Axles (ESAs)

Subtype	Maximum Limit of each Constituent (% by mass)				
	Natural gravel or quarried material	Recycled Materials			
		Recycled concrete	RAP*	Recycled Brick	Recycled Glass^
2.1	100%	100%	0%	0%	0%
2.2			15%	15%	
2.3			20%	20%	20%
2.4				45%	
2.5			45%		

^ Recycled glass shall comply with the MRTS36 Recycled Glass Aggregate.
* Reclaimed Asphalt Pavement

Associated TMR specifications

Enabling use in MRTS05 also enables broader use through many other TMR specifications

To learn more about how TMR is using recycled materials in our roads contact:
E: mr.techdocs@tmr.qld.gov.au

Queensland Government

13 QGOV (13 74 68)
www.tmr.qld.gov.au | www.qld.gov.au

Infographic for facilitating the use of recycled materials as per the MRTS05 updates
Image Source: Queensland Department of Transport and Main Roads (2021).

HIGHLIGHTS REPORT 2020 / 2021

02

ASSET MANAGEMENT

NACOE

ASSET MANAGEMENT

The NACOE Asset Management subprogram has been a priority since the commencement of the NACOE Program. It is focused on advancing asset management knowledge and practises through improved risk assessment and evidence-based performance modelling and the underlying assumptions within these models, and the application of these as part of continuous business improvement.

In addition, the program has included research into new funding strategies that explore life cycle costing implications, particularly considering the risk of major weather events, and flooding across Queensland.

The projects undertaken since NACOE's inception that include publications are listed in the following table. A number of other projects which produced outputs for the sole purpose of guiding TMR remain unpublished.

It is expected that the program will continue to deliver benefits to the department through:

» more robust risk assessment methodologies and asset management tools and models, which will enable the department to better prioritise maintenance and rehabilitation spending through more informed risk-based decision-making

» whole of life cycle cost-based approach to assessing pavement impacts from heavy vehicles

» lifecycle costing of asset management strategies, with a focus on how to improve resilience of the network to rain and flood events with a limited budget and against increasing climatic threats, and

» assisting the department and regions with the implementation of business improvements aligned with ISO55000 and the Austroads Guide to Asset Management.

The continuation of the program into 2021/22 includes the following projects:

» A cross-program infrastructure gap analysis considering network preservation, safety, connectivity, and resilience

» Roadside and road surface delineation Element Management Plan review and development

» Investigation into innovative methods to inform network management of skid resistance

» Improved basis for seal life estimates in asset management: Implementation stocktake and validation of PMB and C170 performance.

LIST OF PROJECTS UNDERTAKEN UNDER ASSET MANAGEMENT STREAM (2013-21)

#	TITLE	PERIOD	PUBLICATION STATUS
A4	Accounting for Life Cycle Costing Implications and Network Performance Risks of Rain and Flood Events	2013 - 16	Published on NACOE Website
A5	Incorporating Uncertainty in PMS Modelling	2013 - 16	Published on NACOE Website
A6	Implementation of Skid Resistance Management Plan (SRMP) Including Knowledge Transfer (Training)	2013 - 15	Published on NACOE Website
A20	Improved Model to Predict the Remaining Life of Sprayed Seal Surface	2014 - 18	Published on NACOE Website
A26	Incorporation of the Pavement Risk Score into the Pavement Condition Index	2015 - 17	Published on NACOE Website
A27	Harmonisation of Pavement Impact Assessment: Updates and Extended Marginal Cost Values	2016 - 17	Published on NACOE Website
A28	Investigate and Compare Life Cycle Cost / Benefits and Performance of Line Marking and Delineation	2016 - 18	Published on NACOE Website
A34	Customer Based Level of Service in Road Maintenance	2017 - 21	Published on NACOE Website
A35	Identification of Residual Risk for each Element and Development of a Funding Allocation Methodology for Elements	2017 - 21	Published on NACOE Website
A44	Synthesis and Dissemination of Best Practice, Value for Money Asset Preservation Solutions and Strategies Based on NACOE and Other National Programs	2019 - Ongoing	Published on NACOE Website

HIGHLIGHTS REPORT 2020 / 2021

NACOE

CUSTOMER-BASED LEVELS OF SERVICE IN ROAD MAINTENANCE

Through this multi-year research project, a need was identified to help road agencies link the Customer-Based Levels of Service (CLoS) requirements to the Technical-Based Levels of Service (TLoS) used in road maintenance. The term Level of Service (LoS) describes how well an asset serves customers, or how well it meets customers' needs and wants.

The purpose of investigating an evidence-based approach of existing levels of service (LoS) is to help road managers and agencies demonstrate the CLoS are being met (as much as practically possible) within the confines of the available budget allocation of their asset management strategy and implementation of TLoS. The project's aim was to demonstrate the statistically significant relationships between CLoS and TLoS across two road classes, urban and rural, which could allow the determination of a customer acceptable level of TLoS. This project was completed across three phases.

1. Year One involved a literature review and a pilot study.
2. Year Two implemented the pilot study methodology on a wider scale, with an extended online video survey.
3. Year Three involved an in-depth statistical analysis of the data collected in the survey, to determine the relationship between CLoS and TLoS, along with implementation solutions.

Descriptive images for survey.
Image Source: NACOE A34 Final Report (2021)

Findings from the literature review were applied to develop a series of measures and indicators used to assess CLoS. The Five CLoS indicators used for assessment were:

» Safety – function, resilience (e.g., shoulder and lane width, safety features, texture, skid resistance)

» Accessibility – amenity/environment (drainage, all weather access, signage)

» Condition – structural, climatic factors (functional and structural measures)

» Reliability – traffic capacity (e.g., adequate number of lanes, traffic management)

» Rideability – travel experience (roughness).

The pilot study assessed two of these indicators, Safety and Accessibility, using a series of individual measures, with initial results indicating there was a relationship between the CLoS and the TLoS.

A similar methodology used in the pilot study was also used for the online video survey undertaken in Year Two.

The Year Two online video survey expanded on the pilot study by assessing four of the five CLoS indicators. Participants in the online video survey were asked a series of open-ended questions, followed by a series of questions asking for ratings of DVR footage. Four urban roads, and four rural roads were assessed as part of the online video survey.

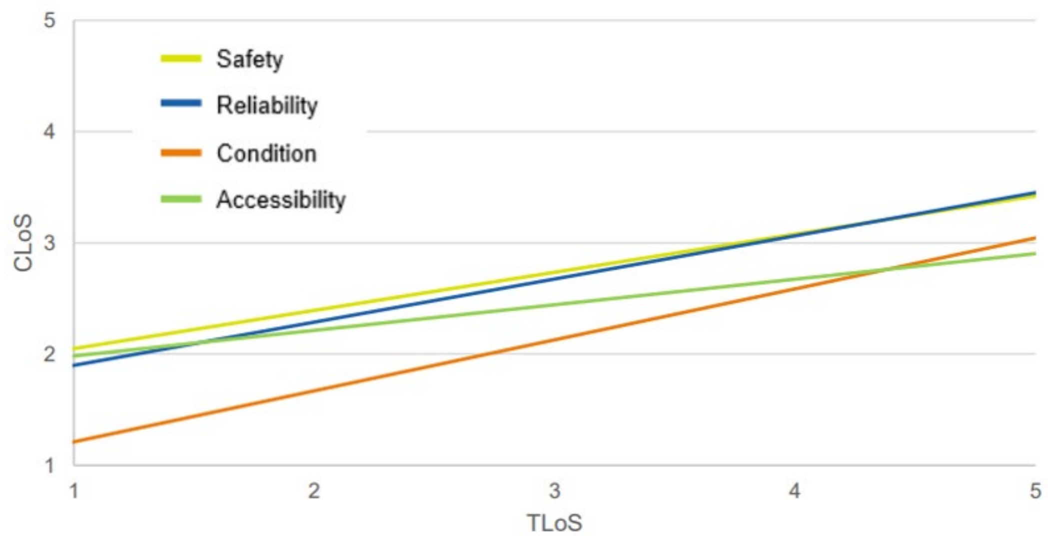
The results of the research survey indicated that most of the measures used to assess each of the CLoS showed positive and statistically significant relationships. Overall, results for each CLoS indicator were as follows:

» The Safety indicator presented a positive correlation and a statistically significant relationship in both the urban and rural environments, with the rural relationship being slightly stronger than the urban relationship

» The Reliability indicator showed a positive and statistically significant relationship in both the urban and rural environments, while this correlation was stronger in the rural environments

» The Condition indicator showed a positive correlation and a statistically significant relationship in both the urban and rural environments, again the rural relationship was stronger than the urban relationship

» The Accessibility indicator also showed a positive correlation and a statistically significant relationship in both the urban and rural environments, while the urban environment correlation and relationship was slightly stronger than the rural relationship. The linear equations developed through the statistical assessment were then used to develop a representative CLoS (on a scale of one to five) for each value of TLoS (on a scale of one to five), for the five CLoS indicators. A linear equation is also presented for Rideability, based on the literature findings.



Summary of all Levels of Service (LoS) relationships.
Image Source: NACOE A34 Final Report (2020-21)

IDENTIFICATION OF RESIDUAL RISK FOR EACH ELEMENT AND DEVELOPMENT OF A FUNDING ALLOCATION METHODOLOGY OF ELEMENTS

TMR addresses increased funding demands from multiple asset elements and the impacts on them from traffic use and the environment. The needs and risks of asset performance are impacted by a combination of factors, (including climate change and flooding). These factors affect different parts of the network, and specific roads and assets (such as structures, slopes, drainage, signs, and lines), in different ways, due to the unpredictability of scale and frequency of impacts.

A need was identified to consider the risks associated with road pavements and surfacing's, (which have been subjected to substantial study), to allow for more rigorous, risk-based planning and programming to help inform their implementation of maintenance works.

The aim of this project is to develop and operationalise a framework for:

» a pavement residual risk model (PRRM)

» a structures residual risk model (SRRM)

» a network operations residual risk model (NORRM project).

These models were developed based on an analytical hierarchical process (AHP). The objective is to deliver a fully documented framework, guidance, and tools to support a comprehensive, risk-based framework to help assist in funding allocations of different asset elements.

The PRRM is made up of five risk dimensions with each dimension built up from 13 risk indicators consisting of two components: the calculation database, and the visualisation of results. A series of charts and maps were used to visualise the PRR score results at various levels of state-wide, district and individual road levels. A forward life-cycle analysis was undertaken to predict the change in risk allowing the effect of the maintenance budget to be considered, and therefore the consequence on risk of different maintenance funding levels over a life cycle.

A review of the impact of PRR weightings for the risk indicators and risk dimensions was undertaken to assess their influence on the PRR score. The impact of maintenance funding on the pavement condition index (PCI) and Regulation Compliance risk indicators and, in turn, their impact on the final PRR score was examined which showed the average PRR score for each district to be relatively insensitive to budget variation. However, the PRR score, risk indicators and specific individual risk dimensions were sensitive to budget variations at a segment level, suggesting that if any further re-weighting of indicators was undertaken, it needs to be balanced against TMR's risk appetite.

The SRRM framework, risk indicators and risk dimensions were developed which considered all bridges and major culverts across the TMR state-controlled road network and is made up of three risk dimensions, with each dimension built up from contributing risk indicators. There are a total of 12 contributing risk indicators in the model. A dataset and the visualisation framework were also developed with preliminary weightings in place. The SRRM tool is now ready for a wider review and initial implementation.

An attempt was made to develop the NORRM framework but was met with the challenging task of gathering the necessary risk indicator data. A change of approach by first understanding the available data and the inventory type was needed and adopted. This was the first step taken with a view to explore combinations of the data currently available to produce risk indicators by means of a case study. This study will inform better preparation of necessary data to complete the model. The NACOE R108 Project (2021) identified the advantages of proactive maintenance of ITS assets which will impact on risk indicator ratings in the NORRM.

The next stage of the project will focus on finalising the quantitative pavement residual risk model (PRRM), and the structures residual risk model (SRRM) for operationalisation as well as finalising the framework for the intelligent transport systems residual risk model (ITSRRM), which was renamed as the network operations residual risk model (NORRM).

No	Risk Dimension	Indicators	Data Source	Score Rating
1	Access Vulnerability	Thorthwaite Moisture Index (TMI)	BOM Rainfall & Temp	1 - 5 rating
		Annual Rainfall	BOM Rainfall	1 - 5 rating
		Traffic (AADT)	TMR ARMIS AADT	1 - 5 rating
		Traffic (%HV)	TMR ARMIS HV%	1 - 5 rating
		Terrain	TMR ARMIS General Terrain	1 - 3 - 5 rating
		Slope Stability	TMR Slope Stability Database	1 - 5 rating
2	Stakeholder & Community	Drainage Condition Index	TMR RMPC Priority	1 - 5 rating
		Pavement Condition Index	TMR Armis Condition	1 - 5 rating
		Reactive Soil Impact	TMR Armis Zone	1 - 5 rating
3	Safety Performance	Asset Safety AusRAP	TMR Ausrap Vehicle Run-Off Score Rating	1 - 5 rating
4	Legislative Compliance	Regulation Compliance	TMR Armis IRI	1 - 5 rating
		Priority Defect	TMR Hazardous Defect Backlog	1 - 4 - 5 rating
5	Operation	Loss Of Access/Function	TMR Road Closure Data	1 - 5 rating

PRRM components summary.
Image Source: NACOE (2020).

NACOE

INVESTIGATION INTO INNOVATIVE METHODS TO INFORM NETWORK MANAGEMENT OF SKID RESISTANCE

Road agencies assess road pavement surface texture, friction, and skid resistance to enhance the safety of the travelling public. Skid resistance management typically adopts a risk management approach where the road network is cyclically tested using a standard test vehicle (see Figure 1.1), and then benchmarked against investigatory levels (which vary depending on the skid resistance and surface texture demand levels for different sections of road).

Although road networks are tested at intervals, the skid resistance varies constantly due to seasonal changes and transient items such as oil and water on the road surface. A more contemporary approach could incorporate the cyclic skid resistance and surface texture test data with real-time 'friction/grip' data provided by modern vehicle technologies.

A review of available literature and projects from Australia and overseas showed potential for road agencies to use harsh braking, traction control use, wiper speed use, regenerative braking, deceleration, speed/torque ratio, and vibrations measured using accelerometers, as surrogate measures to locate areas of the road network that may have low skid resistance and/or texture.

This project investigated new methods of collecting skid resistance and surface texture data by examining the viability of using real-time 'friction/grip' data collected via crowdsourcing. If viable, these new methods could be used to enhance road network management by alerting road agencies in real-time on issues such as oil spills and the long-term issues of reduced skid resistance and may be applied in conjunction with traditional network skid resistance test methods.

The project considered how a comparison trial of standard skid resistance test equipment and crowd-sourced information from vehicles could be undertaken.

Figure 1.1: ARRB's iSSAVe skid resistance testing vehicle.
Image Source:ARRB (2020)

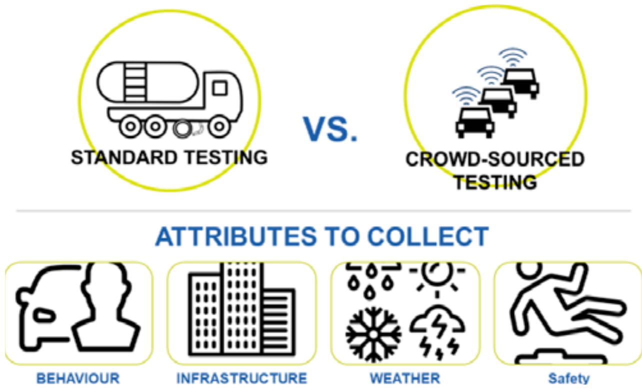


Figure 1.2: Overall project concept.
Image Source: : NACOE (2020)

IMPROVED BASIS FOR SEAL LIFE ESTIMATES IN ASSET MANAGEMENT: IMPLEMENTATION STOCKTAKE AND VALIDATION OF PMB AND C170 PERFORMANCE

Large parts of the Queensland Department of Transport and Main Roads (TMR) road network is sealed with bituminous sprayed seals. In 2016, NACOE project A20 'Scanning and Scoping Technologies That Evaluate the Remaining Service Life of Spray Seals Using Advanced Bitumen Testing Technologies' employed the Dynamic Shear Rheometer (DSR) device to better inform the management of the sprayed seal network by setting a new standard for the evaluation of existing sprayed seal road networks consisting of modified binders. This work was continued through to 2019, under project A20: 'Improved model to predict the remaining life of sprayed seal surface'.

The aim of this project is to validate the A20 Seal Life expression using a comparison between the A20 seal life expression and the condition of sprayed seals based on field inspection.

To ensure that the climactic variations throughout Queensland were taken into consideration, the inspections were undertaken in the Far North and South Coast Districts.

Over 100 seal sites were inspected and compared to the A20 Seal Life expression. A visual assessment was made of the condition of each seal. The visual cracking did not show a strong trend with the Seal Life, and this may be a result of treatment intervention that focuses on managing cracking on sprayed seal and granular pavements.

About half of the sites displayed a mild trend of moderate/extensive distress due to loss of aggregate as the age of the seal exceeded the estimated Seal Life. The maintenance patching showed a weak trend of increased distress as the age of the seal exceeded the estimated Seal Life.

The project included capability development opportunities through enhanced understanding of the performance of Queensland sprayed seal network.

Future stages will continue reviewing the historic method of calculating seal life, assessing the automated cracking data for each of the inspected sites, and comparing the automated and visual cracking assessments.

Photos of seal inspection sites on the TMR sprayed seal network
(Far North and South Coast Districts).
Image Source: NACOE (2021)

03
STRUCTURES

STRUCTURES

Significant investment has been made in the NACOE Structures program in the last five years. Twenty-five projects have been delivered and several outcomes from completed projects implemented into TMR practice.

The NACOE Structures subprogram delivers benefits to the transport infrastructure network in several ways with the following project target outcomes to date:

- Cost savings in design, construction, and maintenance across the network
- Improved bridge monitoring and heavy vehicle access using advanced systems
- Incorporating best practice in managing structures
- Destructive testing and analysis of vehicle interactions on load limited and critical bridges to gain a better understanding of the capacity and performance of these structures
- Enhanced quality of repair practice, forecasting for investment and maintenance decisions
- Improved reporting and risk prioritisation for maintenance programming and network benchmarking
- Introduction of advanced materials and technologies into structures across the network
- Developed TMR Structures Repair Manual for consistent use state-wide
- Provided an updated user manual for WhichBridge, which includes a targeted guide for how to perform common tasks within WhichBridge and WhatIf modules
- Capture corporate knowledge on the historical changes to the WhichBridge algorithms
- Suggested improvements of the WhichBridge algorithms to better reflect the existing network conditions and operational needs
- Development of a functional specification for bridge risk management based on state-of-the-art risk management practice including a roadmap for trialling and implementation
- A technical specification and works procedure were developed for the replacement of transverse stressing bars (TSB) in deck unit bridges
- Best practice review of the removal and replacement of transverse stressing bars and development of a standard method statement and technical specifications for the removal of damaged transverse stressing bars on deck unit bridges
- Developed a bridge jacking methodology and process
- Knowledge sharing in the following areas:
  - the use of advanced assessment technologies and instrumentation of structures
  - bridge risks and gaps in current bridge management practice
  - structures asset management processes
  - how WhichBridge is used in regions and stakeholders' expectations for future improvement
  - factors that affect risk scores and risk score anomalies
  - how to use TMR existing jacking monitoring system for bridge lifting
  - input into TMR training and learning platform in strategic asset management to be used for a broad range of stakeholders, including non-TMR entities such as Local Government.

DISSEMINATION OF LEARNINGS TO DATE

The dissemination of learnings of the overall NACOE Structures program has been occurring through various channels including workshops, seminars, conference papers, and publications on NACOE website. One journal paper and several conference papers have been produced based on the outcomes of the research program to date, including:

- Johannessen, D, Heldt, T, Lake, N, Ngo, H, Frew, J 2021, 'Long-term Monitoring of a Progressively Deteriorating Bridge to Support Safe Operation', Conference Paper: IABSE Congress, January 2021, Christchurch, New Zealand.
- Ngo, H, Hourigan, M, and Lake, N 2019, 'Performance Assessment of Transversely Stressed Deck Unit Bridges with Damaged Transversely Stressing Bars through Field Measurements', Proceeding of 5th Conference on Smart Monitoring, Assessment and Rehabilitation of Civil Structures, Potsdam, Germany.
- Heldt, T, Lake, N, Ngo, H, Seskis, J & Eskew, E 2019, 'Bridge Management–Using Structural Health Monitoring', 9th Australian Small Bridges Conference, 1-2 April 2019, Queensland, Australia.
- Ngo, H and Mir, F 2017, 'Destructive Load Testing of Transversely Stressed Deck Unit Bridges', Proceedings of 10th Austroads Bridge Conference, 2017, Melbourne, Australia.
- Pape T, Mir F & Rooke A 2017, 'Bridge-Vehicle Dynamic Interactions: Results from Recent Load Tests', Proceedings of 10th Austroads Bridge Conference, 2017, Melbourne, Australia.
- Ngo NS, Pape T, Kotze RP and Pritchard RW 2015, Load Testing and In-service Monitoring of Transversely Stressed Deck Unit Bridges, Special Issue: Electronic Journal of Structural Engineering, Vol. 14, Issue 1, pp 85 96.
- Pape T, Kotze R, Ngo H, Pritchard R, Roberts R & Liu T, 2014, 'Dynamic Bridge-Vehicle Interactions', 9th Austroads Bridge Conference, Sydney, New South Wales, Australia.

The following project reports have been published on NACOE websites:

- S1 Measurement of Bridge- Vehicle Interaction Under Live Load (2013/14- 2015/16)
- S2 Guidelines for Monitoring of Existing Structures (2015)
- S3 Deck Unit Bridge Deck Analysis Under Live Load Years 1-4 (2013/14 to 2016/17)
- S3: GUN-Sandgate Road Bridge Load Testing Report (2016/17)
- S6: Review of Bridge Asset Management System- Structures Inspection Manual (2016)
- S15: 'Long Term Performance of FRP Replacement Components and Structures Year 3 (2017/18)
- S19: Geopolymer Concrete Performance Review (2016)
- S26: Virtual WiM – Enriching WiM and Enhancing Decisions (2018–21)
- S28: Review of Performance of Concrete Pipe Culverts (2017/18)
- S29: AS/ISO 13822 Framing Investigation into the Assessment of Deck Unit Bridge and Transverse Stressing Bar Deficiencies (2017/18)
- S31: In-line Timber Bridge Replacement Options (2017/18)
- S43: Improving Structures Asset Management Capability Systems (2018/19)
- S47: Impact of Corrosion Inhibitor Admixtures on Durability of Concrete (2018/19)
- S26: Virtual WiM – Enriching WiM and Enhancing Decisions (2018–21)
- S51: Suitability of the Use of Recycled Aggregate in Concrete Year 2 (2020/2021).

NACOE

REVIEW OF TMR WIM SYSTEMS AND STRATEGIES FOR TRAFFIC DATA COLLECTION FOR BRIDGE ASSET MANAGEMENT: VIRTUAL WIM & HEAVY VEHICLE TRACKING – FEASIBILITY & VALUE

This project investigated ways to help inform TMR's optimisation of heavy vehicle access which provides benefits to the community accessing over 33,000kms of roads and 3,300 bridges. Decision makers aim to balance judgment between productivity and risk to ensure the most safe and economic utilisation of the road network.

The overall aim of this project was to review TMR's Weigh-in-Motions (WiM) systems and identify opportunities for improvement with an emphasis on technologies and systems.

Recent developments in data analytics to link weigh-in motion (WiM) data with other heavy vehicle datasets were used to generate new 'virtual WiM' or vWiM1 datasets. The vWiM approach enhances data quality, coverage, accessibility, application, and the value of TMR's existing WiM datasets (shown in Figure 1).

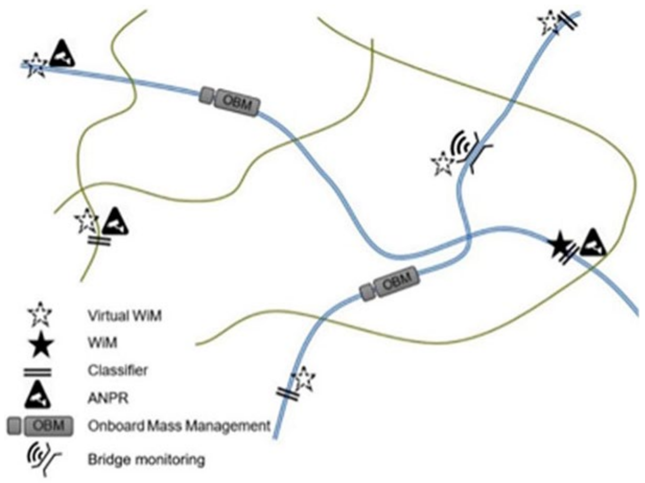


Figure 1: vWiM leverages existing heavy vehicle data collection assets to enhance value, data quality, coverage, and evidence-based decisions. Image Source: NACOE S26 project report (2018-21)

The value from vWiM is generated through better evidence-based decisions relating to the significant investment in transportation and infrastructure made each year, while supporting safe productive access to TMR's infrastructure.

The concepts of vWiM emerged whilst reviewing and analysing 13 months of TMR's WiM systems focused on the load platforms, low loaders, and mobile cranes (as shown in Figure 2) and engaging with stakeholders to prepare a draft Strategic Asset Management Plan (SAMP) for WiM.

The vWiM concepts were further refined while integrating WiM data with other datasets including:

» bridge monitoring
» automatic number plate recognition (ANPR)
» GPS tracking of heavy vehicles (IAP)
» authority to operate (ATO)
» onboard mass management (OBM)
» classifier data.

The project demonstrated the viability and value of vWiM concepts by extrapolating WiM data to more common classifier sites across Queensland.

In addition, the viability of enhancing the quality of WiM mass data by comparing against heavy vehicles of known mass in the traffic stream was demonstrated by integrating GPS tracking, OBM, and ATO data with WiM data. Similarly, bridge monitoring systems were also successfully calibrated using heavy vehicles in the traffic stream.

A prototype tracking tool for Class 1 heavy vehicles was delivered. The tool tracked load platforms which posed the greatest potential risks to bridges and provided a history of loading to better inform access and asset management decisions.

The project recognised that the adoption of the vWiM concepts, as well as a supporting program of continual improvement could help enhance the quality, coverage, accessibility, and linking of datasets. Further development of the engineering and analytics to translate the data into information and knowledge could support better informed decisions that provides further benefit to the Queensland community.

Figure 2: Updates to processing algorithms made wide and heavy loads 'visible' in TMR's WiM and classifier records. Image Source: NACOE S26 project report (2018-21)

SUITABILITY OF THE USE OF RECYCLED AGGREGATE IN CONCRETE

The use of recycled aggregates in concrete production in Australia has gained recent attention and priority. However, widespread adoption in concrete does not appear to have been realised. For example, recycled concrete aggregate (RCA) has been identified as suitable for partial replacement of up to 30 percent of natural aggregate in concrete for footpaths, kerbs, etc. (Cement Concrete & Aggregates Australia 2008), but industry take-up appears to be limited. Recycled materials that have been identified by the Queensland Department of Transport and Main Roads (TMR) for potential use as aggregate in non-structural concrete include:

- crushed recycled concrete (RCA)
- reclaimed aggregate (RA)
- recycled crushed glass (RCG)
- ferronickel slag (FNS)
- power station bottom ash (BA).

The aim of this project was to determine whether recycled aggregates including RCA, RCG, RA, FNS and BA can potentially be accepted by TMR for future use in non-structural concrete applications which typically have a design life of 50 years or less.

The project investigated the viability of three recycled aggregate materials for use in non-structural concrete applications, which are broadly consistent with TMR Normal (N)-Class concrete applications up to 40 MPa characteristic compressive strength. These materials were recycled concrete aggregate (RCA), recycled crushed glass (RCG) and reclaimed aggregate (RA). An additional two recycled aggregate materials, including ferronickel slag (FNS) and power station bottom ash (BA) were investigated as potential fine aggregate replacements.

The viability of these materials for the intended application was investigated through a literature review and industry survey focusing on aggregate properties, concrete performance, concrete durability, availability, and cost of materials. The performance of concrete mixes which utilise recycled aggregates to replace part, or all, of the natural aggregates was reviewed in terms of the workability of the fresh mix, the mechanical properties of the hardened concrete, and their durability and structural performance.

Review of the literature indicated that at high replacement levels (50% up to 100% by mass), coarse or fine RCA concrete is likely to develop reduced strength and durability properties compared to an equivalent mix produced using 100% natural aggregate (NA). However, at replacement levels of up to 30% of coarse RCA, the workability, strength, and durability properties of RCA concrete are likely to be acceptable for non-structural concrete applications. At this replacement level, there is not expected to be an impact on the feasibility of target design lives of up to 50 years as specified for TMR N-Class concrete.

The inclusion of recycled aggregates in concrete has the potential to create environmental and social benefits through diversion of material from landfill and reduction of the need to produce new aggregate material. The research replacement level findings indicated it is likely that this can be achieved without penalty to the performance of the N-Class (non-structural) concrete applications in scope of this review.

MORE FROM NACOE

Other projects funded under the NACOE Program include Network Operations, Road Safety, Sustainability and Heavy Vehicle Management, including:

- targeted efforts to reduce the road toll through investigating key crash types and cost-effective techniques to minimise serious and fatal injuries
- assessing multi-model transportation costs, driving savings through improved network efficiency, and adopting best practice modelling
- streamlining heavy vehicle policy to remove barriers to industry while delivering the best outcomes for the network.

04

ROAD SAFETY

NACOE

ROAD SAFETY

MANAGING CRASH RISK ON NARROW SEAL ROADS

While narrow seal roads (single seal lane e.g., 3.0 – 4.5m with wide formed unsealed shoulders) typically carry relatively low volumes of traffic, these roads are open to Type 2 road trains which play a key role in the economic and social prosperity of Queensland. However, the presence of Type 2 road trains on narrow seal roads can pose a potential safety risk that has not been formally reviewed or quantified. The Australian Road Research Board (ARRB) and the Queensland Department of Transport and Main Roads (TMR), through the National Asset Centre of Excellence (NACOE) partnership, seek to improve the safety of narrow seal roads.

The purpose of the project was to gain a better understanding of the crash risk on Queensland's' narrow sealed network and identify appropriate mitigation measures to assist practitioners in applying consistent safety improvements on the network.

A comparative analysis of the narrow seal network and the low volume high-speed rural two lane, two-way highway network was undertaken to establish the crash rates (per vehicle kilometre travelled) to quantify the historical crash issue on each network. The aim was to classify crash types and crash rates according to road user group (e.g., passenger vehicle, heavy vehicle, or motorcycles) and scenarios (e.g., geometry, time of day and weather condition) to identify if some of these were higher on the narrow seal network.

The comparative analysis identified several crash types and scenarios where the crash risk was higher on narrow seal roads. The characteristics identified as contributing to these crash types were via a desktop review of the locations where the crashes occurred. The findings were used to develop a matrix of countermeasures that could be implemented to reduce the incidence or severity of these crash types on the narrow seal network. Consultation with representatives of TMR in various districts and departments was undertaken to present and discuss the findings of the road safety review and to identify countermeasures that could be considered in a future guidance document.

A technical guidance document was prepared to assist practitioners to identify suitable countermeasures to apply on their narrow seal network. The countermeasures range from low to high-cost treatments. These were developed in line with the Hierarchy of Controls and Safe System approach. A set of fact sheets was also developed to provide practitioners with detailed treatment information and references to existing publications. The fact sheets also allow all practitioners to apply the treatments in a consistent way across the network.

This guidance will assist practitioners to reduce crash risk on their narrow seal network, where application of the guidance should be supported by a thorough network review to ensure the most effective treatments are provided to manage the applicable crash risk.

Crash type	Contributing factors to cause of crash	Safer roads countermeasures			Safer people countermeasures
		High cost	Medium cost	Low cost	Other
Intersection	» Inadequate sight distance to on-coming traffic » High approach speeds » Inconspicuous intersections » Inadequate signage/ controls » Poor gap selection » Poor road surface condition	Realignment- horizontal geometry	Skid resistance	Advance signage	Seat belt use
		Realignment- vertical geometry	Lane (localised) widening and provision of centreline (no sealed shoulder)	Intersection signage	Alcohol & drug testing
		Localised widening with shoulder and delineation	Roadside safety - hazard removal	Speed management	Safe speed
Head on	» Inadequate horizontal and vertical alignment » Overtaking errors » Poor judgement of approaching vehicle speeds » Misjudgement of curve severity » Skidding or loss of vehicle control » Lane carriageway width » Alcohol, drugs, impairment	Realignment- vertical geometry	Lane (localised) widening and provision of centreline (no sealed shoulder)	Delineation (signage and guideposts)	Alcohol & drug testing
		Realignment - horizontal geometry	Rest area/sealed pull-in area	Speed management	Driver reviver
		Lane widening with shoulder and delineation		Edge of road treatment	
Loss of control	» Narrow shoulder or no shoulder » Edge drop/break/stability issues » Poor road surface condition » Pavement drainage » Misjudgement and severity of road curve » Inadequate horizontal and vertical alignment » Roadside objects » Hazards/irregularities on road » Speed distraction, fatique	Realignment - horizontal geometry	Skid resistance	Delineation (signage and guideposts)	Seat belt use
		Realignment- vertical geometry	Slope/batter improvement	Edge of road treatment	Alcohol & drug testing
		Localised widening with shoulder and delineation	Roadside safety - hazard removal	Speed management	Safe speed
			Sealed pull-in area		

A suite of countermeasures (high-cost to low-cost) for narrow single-lane sealed roads.
Image Source: NACOE Report R99: Identification of Safety Risk and Development of Mitigating Treatments for Narrow (4 m) Sealed Roads (2020/21)

05

NETWORK OPERATIONS

NETWORK OPERATIONS

DEVELOPMENT OF HYBRID DATA MODEL PROTOTYPE FOR THE ENHANCED COST OF CONGESTION (COC) METHODOLOGY

TMR aims to provide an automatic system to report the cost of congestion (CoC) of a network with roads from different jurisdictions (e.g., TMR and local governments). A hybrid data model, which blends in data from multiple sources (including detection loops, Bluetooth devices and probe vehicles), is considered the ultimate data source.

This project was set up to develop a web-based analysis and visualisation software prototype that aimed to test the quality and performance of hybrid data, when compared to currently available individual data sources. Year One of the project developed a web based CoC prototype system that incorporated multiple data sources including the intelligent hybrid data model and conducted the enhanced CoC calculation and reporting at link, route, and network levels.

Year Two further enhanced the intelligent hybrid data fusion rules and quality, provided a more in-depth CoC comparison between different scenarios, and refined the prototype system functionality and useability. Year Three expanded the hybrid data range from 4 to 16 months for trend analysis, data behaviour investigation and data quality validation. It also finalised the CoC prototype and showcased the main applications of the prototype.

Using the developed datasets and prototype web software, the project investigated the data behaviour between hybrid data, detection loops (STREAMS), probe data (HERE) and Bluetooth within the City of Gold Coast. It was found that the use of hybrid data was able to improve the data coverage of STREAMS from 62% to 85%. For both freeway and motorway links, the hybrid speed was able to capture the speed profile characteristics from other individual data sources. The hybrid speed value was also found to moderate the volatility by applying appropriate speed weightings for the data sources in fusion logic, based on data quality and sample-size considerations. The results suggest that hybrid data can give users greater confidence in quality, accuracy and coverage when compared to other individual speed data sources.

The project also showcased the function and capability of the prototype software for CoC monitoring, network performance evaluation and before-and-after studies. Case studies were conducted to compare the network and route-level CoC for hybrid datasets and STREAMS. As hybrid data was able to improve the data coverage, capture the key speed profile characteristics of individual data sources and mitigate the volatility and variability of some raw data, the case study results suggested that STREAMS data alone may underestimate the CoC of motorways and overestimate the CoC of arterials.

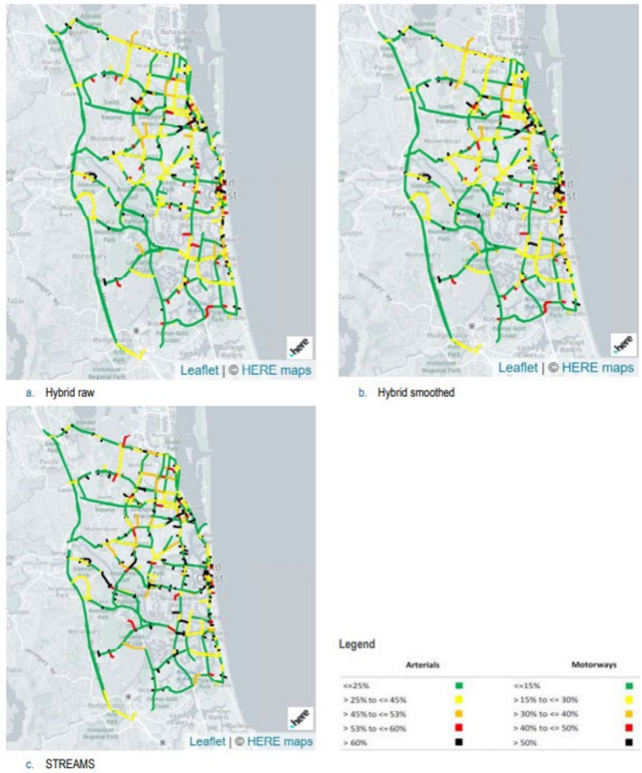
Further, the COVID-19 case study demonstrated that the network daily vehicle-kilometres travelled and CoC were significantly impacted by COVID restrictions over the months of March and April 2020. The quality and accuracy of hybrid data was tested and enhanced to a satisfactory level to support a scalable roll out of hybrid data to broader scope.

The research findings suggested:

» expanding the hybrid data to serve broader TMR road networks (e.g., the South East Queensland network) to use, test, and benefit from the hybrid data

» utilise the knowledge gained to support more case studies, project evaluation and incident impact analysis at link, route, and network levels

» using the datasets developed for the Gold Coast network, travel time reliability cost could be incorporated as the next step in the prototype upgrade.



Variation from the PSL for the entire Gold Coast study area visualised by different data sources. Image Source: ARRB Toolbox (2021)

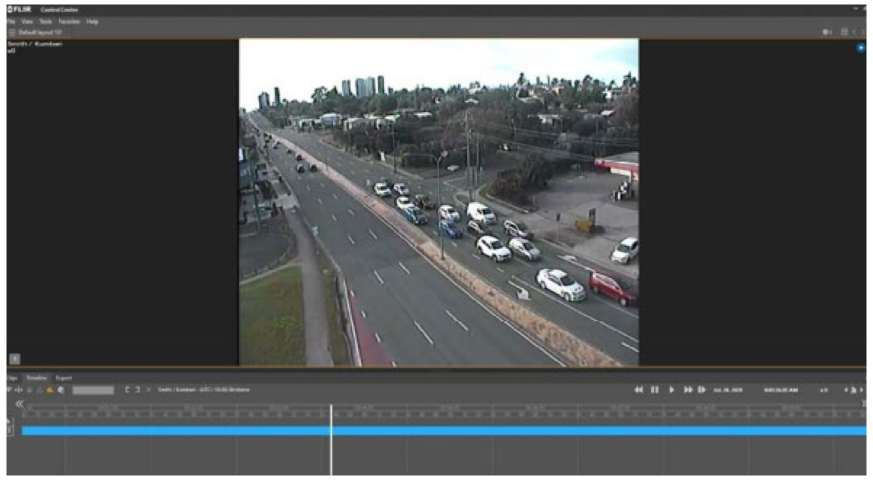
REAL-TIME DETERMINATION OF SPARE CAPACITY OF ROUTES FOR ENHANCED MANAGEMENT OF CONGESTED ROAD NETWORKS

This project investigated the real-time determination of spare capacity of routes for enhanced management of congested road networks. Spare capacity is defined as the difference between the design capacity (i.e., theoretically how many vehicles can a road serve) or the operational capacity (i.e., the actual number of vehicles a road is able to serve for sustained periods of time) and the realised flow. A knowledge of spare capacity in real-time would lead to enhanced traffic management strategies such as providing more accurate traveller information and the potential to better manage/optimise traffic signal control strategies.

This project developed a prototype in Year Two (with modifications made in Year Three) to identify saturated traffic conditions, and hence spare capacity, using the available traffic data. A calibration and validation of this prototype was then undertaken via a case study comprising of two arterial routes on the Gold Coast using Bluetooth, CCTV, and detector data analysis.

The calibration of the prototype required determining the threshold capacity values, for each traffic lane, which were undertaken through visual inspection of volume-occupancy plots from departure, arrival detectors, and NPI data. The capacity thresholds were then validated at a high level against the CCTV footage to determine whether the traffic state of the chosen values accurately reflected the ground truth. Some slight variations were made to produce a modified prototype showing better results, i.e., a more realistic representation of the saturated traffic conditions.

Furthermore, the modified prototype continuously forecasted saturated traffic conditions for a major portion of the day at few sites with some data limitations identified, such as lane detector malfunctioning, etc., which were documented in the project report. The prototype was able to identify periods of saturated traffic conditions during the peak hours with no identification during off-peak hours as expected. This finding suggests a reasonable accuracy of the prototype to establish saturated traffic conditions in real-time experienced in real-world.



Sample video of site data (CCTV footage).
Image Source: R77 NACOE project report (2021)

REVIEW OF ROAD OPERATIONS INTERVENTIONS LEVELS

Queensland's Road System Performance Plan (QRSPP) provides the milestones for road system investment to aid in delivering Transport and Main Roads outcomes for the State-controlled Road (SCR) network. This provides detailed direction for SCR network investment in Maintenance, Preservation and Environment (MPE) and Road Operations (RO) Investment Programs.

Road network operations is becoming increasingly more important relative to construction and maintenance with intelligent transport systems (ITS) playing an increasing role. Up to and through 2020/21, Element 34: Traffic management was responsible for funding the activities for operating and maintaining the road network, including operational systems and assets (traffic signals, ITS, and traffic management systems). The governance for Element 34: Traffic management was managed under the Road Operations (RO) Investment Programs.

This project is a continuation and evolution of the work done in 2014 on reviewing how Element 34 activities were delivered across the state and at what levels. Due to the growth in ITS solutions and in traffic, a need was identified to do an updated review on the benefits and efficiencies provided by the investment.

Through undertaking a literature review, data review, and working with the TMR Regions and Districts, the project findings associated with the following key project objectives included:

1. Map the existing suite of Element 34 funded activities to the relevant operational services and define how they align to TMR's transport system objectives.
2. Provide clarity and transparency for delivering the Element 34 funded program of works into the future.
3. Assist with investment planning optimisation and hence realise further efficiencies and effectiveness gains for TMR.

One key finding was the benefits of finalising the restructure of the road operations suite of elements. This restructure was successfully undertaken in 2021 with Element 11, 13, 30 and 34 being redistributed to a modernised new Element structure. The new Element structure will greatly assist TMR with ensuring more optimisation investment in future road network operations outcomes.

06

SUSTAINABILITY

NACOE

SUSTAINABILITY

SUSTAINABILITY ASSESSMENT TOOL (SAT)

New and emerging pavement technologies provide an opportunity to increase use of recycled or non-standard materials in road construction and maintenance.
In partnership with the Western Australian Road Research and Innovation Program (WARRIP), NACOE helped co-develop a Sustainability Assessment Tool- a Life Cycle Assessment tool for assessing and comparing innovative and traditional pavement designs.

The project focused on the development of an Excel-based proof-of-concept for cradle-to-grave assessments, measuring the whole-of-life greenhouse gas emissions and other environmental and consumption indicators as well as financial costs of pavement options. The tool can break these down by life stage and pavement component to focus on "hot spots" and areas for improvement, including structural design, material and product selection, maintenance regimes and end-of-life options.

Further features developed include:

» Extensive data libraries with over 80 pavement materials

» Reporting on a variety of environmental and consumption indicators including GHG, other air pollutants, recycled material use, IS Enviropoints, and energy and water consumption

» Scenario and sensitivity testing for sustainability outputs and economic indicators

» Evaluates "use phase" vehicle emissions for the design, including alignment

» Aligns with Infrastructure Sustainability Council's (ISC) ratings process and requirements.

SAT can be used in pavement planning and design phases to inform material selection, construction, maintenance, and end-of-life options. Whole of life planning and design can lead to better environmental, pavement performance and economic outcomes for the Queensland Department of Transport and Main Roads (TMR).

Ultimately, implementation of the tool will help drive the adoption of innovative pavement technologies and designs that contribute to Queensland's emissions and waste reduction targets, landfill diversion and increased use of recycled materials, and delivering on its vision to become a sustainable, low-waste, circular economy.

DEVELOPMENT OF FRAMEWORK FOR FISH PASSAGE IN CULVERTS

Currently in Queensland, waterway barrier works approvals are required for the installation of culverts in waterways where fish passage is of concern. The Queensland Department of Agriculture and Fisheries (DAF) Accepted Development Requirements for raising or constructing Waterway Barrier Works (ADR) specify full-height corner-angle baffles where baffles are stipulated.

Previous investigations into the engineering and hydraulic performance of full height corner-angle baffles identified that baffles have a significant impact on the hydraulic efficiency of culverts and, depending on installation method, can cause structural integrity concerns for culvert units.

Year One of the project conducted a literature review and a field trial of alternative baffle options as well as the review of box culvert hydraulics undertaken by University of Queensland (UQ). Year Two of the project investigated alternative baffle options for use in precast box culverts on Queensland waterways where waterway barrier works approvals for fish passage are required (red and purple waterway categories).

Designs were discussed with precast manufacturers and composite material manufacturers, and limitations of each manufacturing approach were captured. Ultimately, the 50mm full-height triangular baffle was selected as the most promising option for investigation through CFD modelling and progression to further prototyping as part of a future project.

Modelling using computational fluid dynamics (CFD) of the 50 mm triangular baffle and DAF baffle was undertaken to investigate the comparative performance of the two options. It was found that the 50 mm triangle could produce under all discharge scenarios studied:

» a contiguous low velocity zone (LVZ) with flow velocities at or below 0.3 m/s was generated for all slope/discharge scenarios modelled

» the LVZ was narrower for the 50 mm baffle compared to the 150 mm baffle

» lower turbulence was generated by the 50 mm baffle compared to the 150 mm baffle

» for the culvert size modelled (2.4 x 1.2 m), minimal reduction to hydraulic capacity was observed for the 50mm triangular baffle, compared to a 6.25 % reduction for the DAF baffle.

These outcomes support the theory that a smaller LVZ can provide acceptable fish passage o utcomes for small-and-larger-bodied fish, and it appears to be technically viable to prototype and subsequently implement the 50 mm triangular precast baffle. A basis for further prototyping of the 50 mm baffle design was developed and documented with input from the research team and industry precast manufacturers. A future trial could explore the option for inclusion of the 50 mm triangle as an option within the DAF Accepted Development Requirements.

The research conducted to date indicates this baffle option would deliver benefits in terms of-

» improved hydraulic efficiency

» reduced costs

» easier installation

» maintaining comparable or better fish passage performance when compared to the current full-height DAF baffle.

HIGHLIGHTS REPORT 2020 / 2021

DISPERSIVE SOIL MANAGEMENT

Soils with slaking and dispersive properties are common across Queensland. While often undetected and unproblematic in the natural environment, soils with these properties cause problems for infrastructure as they are highly erodible in the presence of water.

- Slaking refers a lack of ability in the soil to support the structure of the soils under certain environmental conditions, such as excess water infiltration
- Dispersive soils (otherwise known as sodic soils) are soils with a chemical imbalance (e.g., high sodium) and/or excessive mechanical disturbance (e.g., lack of organic matter).

The high susceptibility to erosion poses a potential substantial risk to the Queensland Department of Transport and Main Roads' (TMR's) asset durability (due to subsidence of supporting land) as well as:

- the safety of the travelling public due to erosion of road shoulders (or beneath) the road
- legacy liabilities associated with degraded areas within the road corridor to be managed under Maintenance, Preservation and Operation's (MPO) Element 3 Degraded areas
- degradation of landscape biodiversity through loss of topsoil
- the financial and environmental costs incurred during construction associated with disposing of these materials and importing non-dispersive materials.

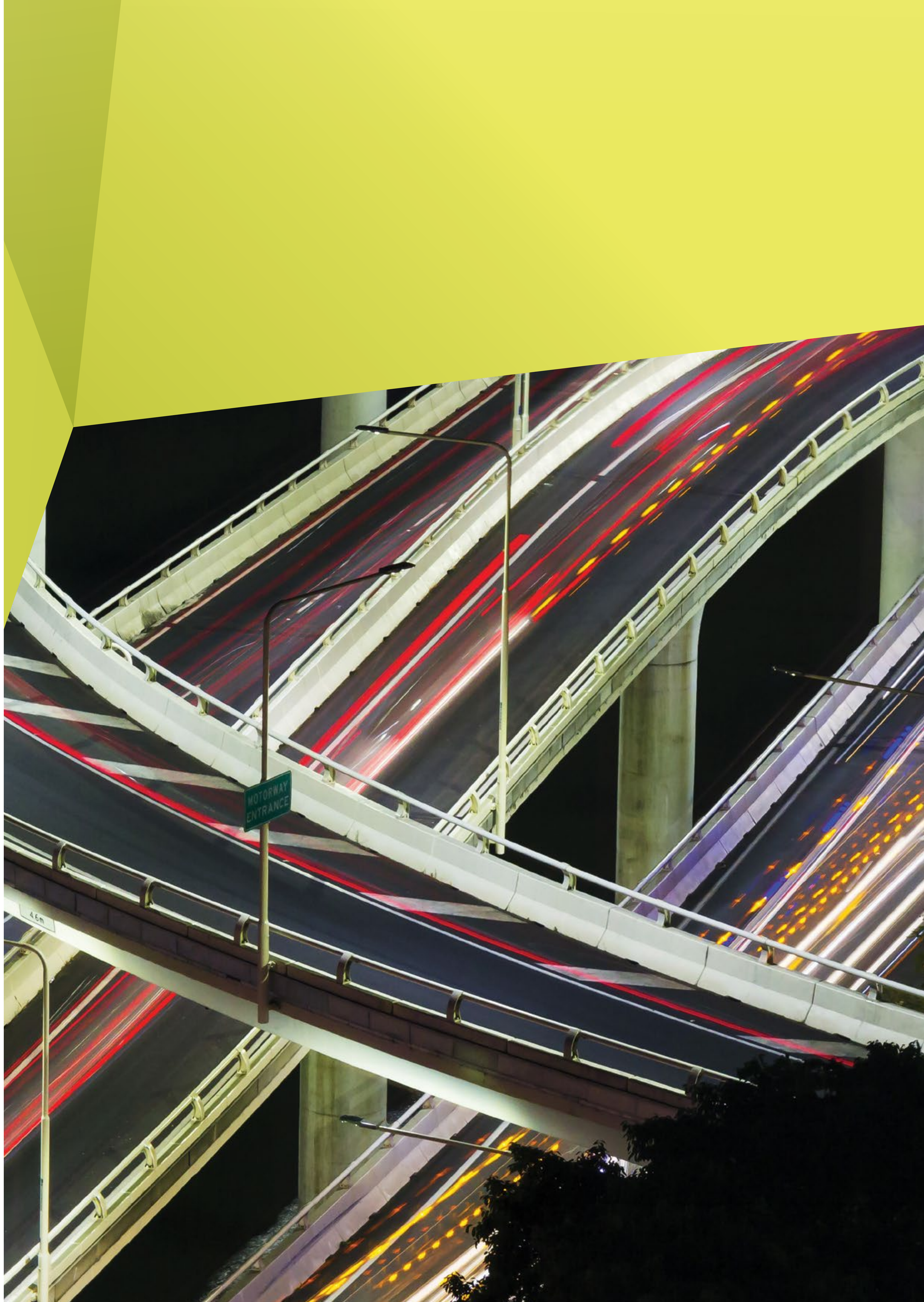
Erosion resulting from disturbed dispersive soils is also a major contributor of sediment loads to waterways from road corridors, affecting the health of downstream areas including the Great Barrier Reef. The aim of this project was to review scientific publications with a view to inform possible options to integrate effective management of dispersive and slaking soils into standard earthworks processes through TMR technical specifications.

The project delivered:

- a Technical Note: Managing Dispersive and Slaking Soils on Infrastructure Projects
- a revised test method based on Emerson test for laboratory analysis of dispersive and slaking properties
- improved procedures for identifying and evaluating risks for dispersive and slaking soils in pre-construction.

At a high level, these amended technical publications provide clarity of process and roles, revised tests method to improve accuracy and provision of amelioration of dispersive soils as part of earthworks, including new pay items within the schedule.

Examples of erosion due to dispersive soils.
Image Source: Queensland Department of Transport and Main Roads (2020)



GET INVOLVED

The NACOE Program runs on a rolling four-year basis, with projects generally spanning one to three years. The program heavily relies upon the input and collaboration between TMR, ARRB and industry personnel to develop ideas for projects across the seven key discipline areas of pavements, asset management, structures, network operations, road safety and heavy vehicle management. Any suggestions for projects can be submitted through the NACOE website **nacoe.com.au** or by sending an email to **info@nacoe.com.au**.

FEEDBACK AND CONTACT DETAILS

The NACOE Agreement Managers can be contacted with any feedback or enquiries regarding the program or for information on specific projects.

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