NACOE

TEN YEARS OF EXCELLENCE

2013 - 2023

10 YEAR HIGHLIGHTS REPORT

2013 – 2023

AN INITIATIVE BETWEEN

Queensland Government | NTRO NATIONAL TRANSPORT RESEARCH ORGANISATION

Acknowledgment

We want to acknowledge our partners, the Queensland Department of Transport and Main Roads (TMR) and the National Transport Research Organisation (NTRO), formerly the Australian Road Research Board (ARRB), for developing the NACOE Program over the past ten years.

We also thank and acknowledge the organisations, universities, delivery partners, and industry associations collaborating on NACOE projects. Their valued support and input make much of our road research work possible.

Additionally, NACOE recognises its valued research partners;
Australian Flexible Pavement Association (AfPA), The Western Australian Road Research Innovation Program (WARRIP), Austroads, Brisbane City Council, Tyre Stewardship Australia, Gold Coast City Council, University of the Sunshine Coast (UniSC), Central Queensland University (CQU), The University of Queensland (UoQ), Queensland Government Department of Environment, Science and Innovation (DESI), University of Southern Queensland (UniSQ), Queensland University of Technology (QUT).

About our Partners:

Queensland Government

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. It plans, manages, and delivers Queensland's integrated transport environment for sustainable road, rail, air, and sea transport solutions. TMR's vision is to create a single integrated transport network that is accessible to everyone. The integrated transport planning approach ensures that TMR contributes to people's quality of life, Queensland's economic well-being, and a sustainable environment.

NTRO NATIONAL TRANSPORT RESEARCH ORGANISATION

National Transport Research Organisation (NTRO)

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

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NACOE'S HISTORY 2013-2023

In December 2012, the Queensland Department of Transport and Main Roads (TMR) and the Australian Road Research Board (ARRB) signed a new agreement to create a National Asset Centre of Excellence (NACOE) in Queensland. NACOE commenced in July 2013, and June 2023 marked the completion of ten years of collaborative research between the two organisations. Since 2015, the annual highlights reports have reflected on progress in the preceding financial year across the initiative's sub-programs, including knowledge dissemination and capability development. As 2023/24 marks a ten-year milestone, this report provides an overview of some of the key achievements and projects over the life of NACOE and documents how the research undertaken by NACOE has benefited Queensland and the broader transportation industry.

2013 - 2015: NACOE commenced in July 2013, focusing on achieving 'quick wins' with solid cost savings prospects. The practical applications of the program's research were evident across the first two years, demonstrating that TMR can achieve benefits far greater than the costs with confidence. In 2014, ARRB Group Managing Director Gerard Waldron and TMR Director-General Neil Scales extended funding of the NACOE research program, further solidifying its effectiveness. By 2015, the program had published 16 reports, delivered 93% of milestones and completed 31 projects with a benefit/cost ratio of 6. Client and stakeholder feedback from the period provided to TMR project managers highlighted strong support for the program within the department and industry.

2016: As the NACOE program matured and early research objectives were completed, an increased focus was placed on seeking joint funding from external partners, including industry and universities, which was realised through partnerships with Australian Asphalt and Pavement Association (AAPA), Western Australian Road Research and Innovation Program (WARRIP), Austroads, Brisbane City Council, Department of Environment and Science, Tyre Stewardship Australia, Gold Coast City Council, University Sunshine Coast, CQUniversity, The University of Queensland, and the University of Southern Queensland.

In 2016, NACOE were the winners of the Distinguished Scientific Papers - Asia Pacific Award for research into the cost of congestion on a multi-modal basis. This project measured the congestion cost for cars, freight, buses, bicycles and pedestrians. The findings from two completed case studies were presented at the ITS World Congress in Melbourne in October 2016. Lead authors Clarissa Han of ARRB and Kath Johnston of the TMR were awarded honours and recognised for their significant contributions to the industry. The findings were also presented and discussed at a specialist workshop at the ARRB Conference in November 2016 in Melbourne.

During this period, NACOE was awarded further success for research into incorporating uncertainty in pavement management system modelling. This research aimed to apply a probabilistic, quantitative, risk-based approach to modelling pavement asset performance, allowing for an appropriate degree of uncertainty in forecasting network conditions. The project team comprised of Peter Kadar, Tim Martin and Ranita Sen of ARRB and Michelle Baran of the TMR. Peter Kadar presented a joint paper based on elements of the research at the 9th International Conference on Managing Pavement Assets in Alexandria, Virginia (USA), May 2015. The paper, Addressing Uncertainties of Performance Modelling with Stochastic Information Packages—Incorporating a Measure of Uncertainty in Performance and Budget Forecasts won the Innovation Award at this international event.

2017: In 2017, NACOE's fifth year, with 35 publications, industry recognition, and an agency benefit/cost ratio greater than 10, the impact of our work was undeniable. A strong focus was placed on implementing the findings of the completed projects from its first four years, further solidifying NACOE's position as a leader in the field. Some notable implementations from this period included the delivery of high-modulus asphalt—EME2—on significant projects in Queensland. The Gateway Upgrade North (GUN) project involved the placement of 10,000 tonnes of EME2, representing the most extensive use of this innovative product in Australia to date. Around the same time, the Brisbane Port used a further 50,000 tonnes of EME2 to improve its Port Access Road.

Additionally, 2017 saw a notable increase in the use of recycled crumbed rubber in reseals in Queensland. Using crumbed rubber reseals in South West Queensland involved cartage of considerable binder volumes up to 1000km from Brisbane. This project was honoured with an award for the best innovation at the National Australian Asphalt Pavement Association Awards in Sydney in 2017. In addition to improving the durability of bitumen seals, using crumbed rubber in sealing and asphalt work provides a beneficial application for waste tyres, which are otherwise stockpiled or burnt. TMR also oversaw increased usage of innovative foam bitumen stabilisation, which improved pavement resilience when subjected to flooding. NACOE's research into high-risk roads was also acknowledged in this period. TMR initiated the Higher Risk Roads process to develop project proposals for safety improvement projects to reduce Queensland's fatal and severe injury crash rates. Identifying and treating high-risk road sections involved a network analysis, safety risk assessments, options analysis, and a business case for the preferred options. As a result, this project improved TMR's road engineering capability by improving road safety and developing solid relationships between regional staff and the central Safer Roads team in Brisbane. This project won the Implementing Agency Applied Research Award at the Inaugural Australian Road Research Board Award Gala Dinner at the Melbourne Aquarium.

Additionally, research into long-haul S1.8R crumb rubber bitumen was honoured. Modifying bitumen with crumb rubber from truck tyres improved the bitumen properties so that sprayed seals are more durable and less prone to bleeding, cracking, and stone loss. SAMI Bitumen Technologies and SRS Roads (COLAS) produced a crumb rubber bitumen that complied with TMR's S1.8R specification using crumb rubber extracted from old truck tyres. The "pre-blended" crumb rubber bitumen was formulated to stabilise storage during prolonged heating and transport. SAMI supplied the S1.8R bitumen from their Brisbane facility to various resealing sites across the South Western district of Queensland. The binder was transported up to 1100km without the rubber particles dropping out of suspension or the binder properties degrading during transport. The development of long-haul crumb rubber bitumen means more use can be made of these binders in resealing the rural road network outside Brisbane, leading to sustainable performance and economic benefits to TMR.

2018 - 2019: Ever expanding its sphere of influence, in 2018-19, NACOE focused on bringing the best innovative technologies from overseas and working with our industry partners to adapt these technologies to Queensland conditions. The program worked with excellent industry partners, including AAPA, Tyre Stewardship Australia, the City of Gold Coast, and WARRIP. Through these partnerships, NACOE progressed its investigation into Intelligent Compaction (IC) and its potential role in future road construction and increased the use of recycled tyres on Queensland pavements.

NACOE also delivered a pilot specification for crumb rubber modified open-graded and gap-graded asphalt.

In a first for Australia, the specification was successfully trialled on a live road implemented in collaboration with the City of Gold Coast. In June 2019, the NACOE program was presented with the Queensland State Innovation Award by the Australian Asphalt Pavement Association (AAPA), which acknowledges innovation in research initiatives.

TMR Director General Neil Scales OBE and
ARRB State Business Leader (Queensland) Matthew Bereni
Source: ARRB (2022)

2020: With an unprecedented turn of events due to the pandemic, our people and industry partners were introduced to a new way of working. One thing that did not change was NACOE's ability to remain strong as a team to deliver the program of work.

In 2020, the program broadened its commitment to driving positive change in the transport sector by providing sustainable solutions for Queensland and to help deliver on its vision to become a sustainable, low-waste, circular economy. Research into assessing the life cycle benefits and greenhouse gas emission reductions of using innovative pavement solutions was undertaken to support the industry's uptake of recycled materials in pavement construction. Through partnerships, the program developed a pilot project-specific technical specification for using IC, which was successfully trialled on the Ipswich Motorway Upgrade Stage One (Rocklea to Darra) project. Additionally, NACOE developed a new specification for recycled crushed glass (RCG), which specified the requirements for using RCG in asphalt and unbound granular applications.

NACOE's efforts were not solitary. We conducted a full-scale pavement trial in collaboration with the Logan City Council at Logan Street near Eagleby, QLD, demonstrating the power of collective action in evaluating the effectiveness of geogrid reinforcement in flexible pavements under real pavement conditions. This collaborative approach was also evident in our increased investment, which saw the NACOE program team up with WARRIP to develop a Sustainability Assessment Tool (SAT4P). This tool calculates innovative pavement design options' economic and environmental sustainability benefits, significantly contributing to Queensland's waste reduction.

The dissemination of key learnings also saw three research papers detailing the study process and findings of project R54: Automating Road Data Collection for Road Condition Monitoring and Road Safety Improvement, which have been presented and published in conferences and a symposium in 2020.

NACOE

"Over the past ten years, the NACOE research program has advanced innovations in TMR's planning, design, construction and asset management activities, helping keep Queensland at the forefront of sustainable infrastructure and delivering economic benefits.

The program's outcomes have led to the adoption of better, more climate-friendly infrastructure solutions that reduce waste and emissions. In addition, pavement resilience innovations are reducing the impact of environmental conditions. In the case of severe weather events, this means cost savings and less disruption to network operations from road closures and repairs."

Julie Mitchell
Deputy Director General (Infrastructure Management and Delivery)
Queensland Department of Transport and Main Roads

2021 - 2022: The research undertaken between 2021 and 2022 contributed to implementing best practice frameworks and fostered a culture of knowledge sharing and exploration of ground-breaking innovation across Queensland and beyond. Through this collaborative approach, NACOE was able to leverage our collective expertise and drive transformative changes in the transport infrastructure sector. Significant strides were made in advancing our understanding of recycled materials technologies. NACOE took crucial steps towards a greener, more resource-efficient future by focusing on sustainable infrastructure solutions.

Working with recycled materials suppliers and the Ash Development Association of Australia (ADAA) to develop and optimise recycled material blends. NACOE also collaborated with Griffith University researchers to utilise their silicon and silicon carbide microsensor technology to generate real-time data and monitor slopes with significant landslide hazards. In the safety space, NACOE developed a wireless sensor network to help predict and prevent rainfall-induced landslides and consulted with the Australian Flexible Pavement Association of Australia (AfPA) and other state transport agencies to address the high-priority issue of improving safety at roadworks sites.

Following the devastating Black Summer bushfires (2019-2020), NACOE, in collaboration with WARRIP, developed a practical framework. This framework embeds the consideration of bushfire prevention, preparedness, response, and recovery (PPRR) into the project life cycle of transport infrastructure. The research delivered practical, implementable advice for road agencies, helping them manage the potential risk to road infrastructure caused by the impacts of bushfires and safeguard our communities.

2023 and beyond: In 2023, NACOE was recognised by the Australian Flexible Pavement Association (AfPA) as the Queensland State Award winner in the Innovation category for research into implementing Intelligent Compaction in Queensland. This occasion marked a remarkable milestone not only for NACOE but for the industry and innovation coming into practice sooner through the collaboration and dedication of our team and industry partners.

Since its inception in 2013, the National Asset Centre of Excellence has established itself as a leading force in Queensland's transport research landscape. Its commitment to delivering value for money is evident in the program's track record, fostering a more sustainable, safer, and efficient transport network for the state.

The latest Agreement has a broad scope and includes committed funding for capability development, research, and technology transfer. Across the current seven sub-programs, NACOE continues delivering strong economic and sustainability benefits to the department and the broader Queensland community, with the potential for economic savings being a key factor in project selection and delivery.

Pacific Motorway M1 Eight Mile Plains to Daisy Hill upgrade

Source: TMR (2017)

IN 10 YEARS NACOE HAS:

- Completed almost 400 projects.
- Published over 160 reports.
- Delivered a multitude of workshops, training sessions and webinars to thousands of attendees.
- Presented findings at multiple international conferences each year since 2013.
- Collaborated with a broad range of industry partners, including local governments, universities, industry associations, and delivery partners.
- Won multiple awards for collaboration, innovation, and research/scientific papers.
- Conducted numerous field trials.
- Seen the implementation of research findings across tens of thousands of kilometres of Australia’s road network.
- Benchmarked asset management practices and identified industry best practices, leading to significant cost savings across the state's infrastructure.
- Lead Australian research on sustainable pavement materials like EME2, recycled materials, natural fibres and construction methods to extend pavement lifespan and reduces long-term maintenance costs.
- Played an instrumental role in the reduction in the required thickness of heavy-duty asphalt pavements has led to savings in construction costs and construction time, as well as delivering sustainability benefits to the community through reduced demand for road-building materials.
- Improved asset management modelling, tools and practices that have reduced agency and road user costs.
- Reduced ongoing agency costs due to improved whole-of-life transport solutions, including building resilience in extreme climatic events.

Agreement Manager Joe Grobler, Pavements Stream Leader Sam Afkar, and Deputy Director General Julie Mitchell at the 2023 AfPA Awards.

Image Source: NACOE (2023)

Aerial view of contuction works Bicentennial Road interchange

Source: TMR (2017)

GOVERNANCE
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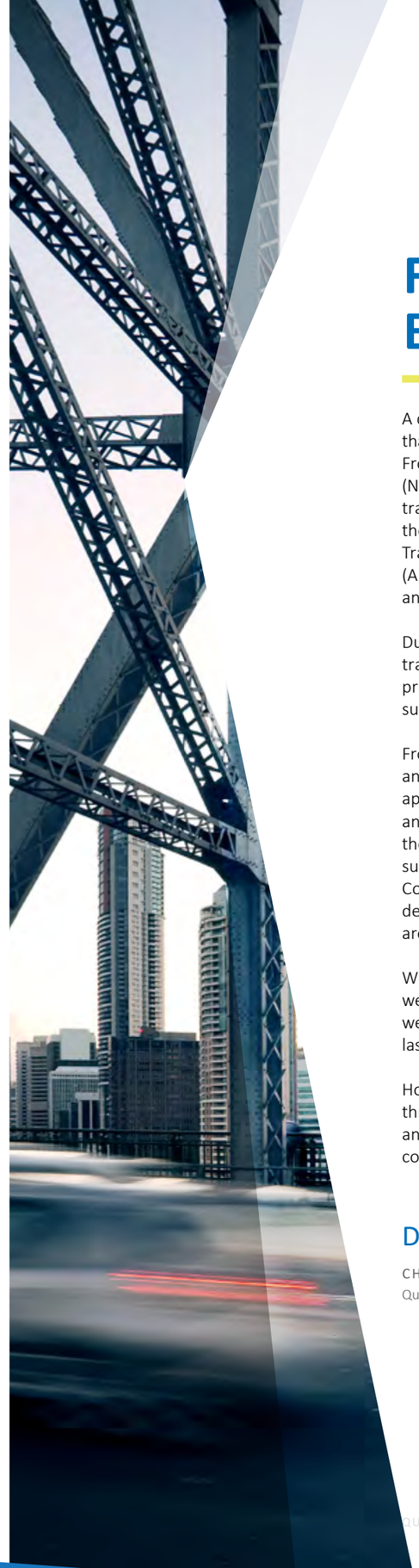

NACOE

FOREWORD
BY THE BOARD

A decade ago, a vision emerged to establish a collaborative research program that would deliver tangible benefits for Queensland's transport sector. From that vision, the unique and impactful National Asset Centre of Excellence (NACOE) was established, playing a pivotal role in shaping Queensland's transport sector over the past decade. The 10-Year Highlights Report celebrates the remarkable collaboration between the Queensland Department of Transport and Main Roads (TMR) and the Australian Road Research Board (ARRB), now known as the National Transport Research Organisation (NTRO), and serves as a testament to the journey undertaken by NACOE.

During these ten years, TMR's partnership with NTRO has unlocked innovation, translated new knowledge into practice and implemented international best practices, which have ultimately led to a safer, more efficient, and more sustainable transport network for Queensland.

From its conception, TMR recognised the power of collective expertise and looked to proactively grow the partnership with NTRO as a leader in applied research whilst fostering productive relationships with industry and the university sector. NACOE has had a singular determination to push the boundaries of what's possible, leading to real-world improvements in sustainability, safety and efficiency. Award-winning research on Intelligent Compaction, a revolutionary technology for road construction, and the development of a bushfire risk framework for transport infrastructure are just a couple of examples.

With a focus on delivering economic and sustainability benefits, NACOE is well positioned for the future, and as we celebrate NACOE's 10th anniversary, we acknowledge the remarkable achievements and the lasting impact of the program.

However, this is just the beginning. The dedication of the joint NACOE team through the continued collaboration with NTRO and our industry partners, and the unwavering commitment to innovation will ensure the program's continued success well into the future.

Dennis Walsh

CHAIR | CHIEF ENGINEER (ENGINEERING AND TECHNOLOGY)
Queensland Department of Transport and Main Roads

BENEFITS OF NACOE

NACOE continues 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 (IC) 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 the thickness of heavy-duty asphalt pavements has led to savings in construction costs, construction time and material, resulting in sustainability benefits to the community
- Providing environmental benefits through improving technologies to increase the use of recycled vehicle tyres in sprayed seals and asphalt
- Leading the way in the technologies that enable use of higher percentages of recycled asphalt pavements
- Providing research outcomes to reduce ongoing agency costs, resulting in improved whole-of-life transport solutions
- Informing improved asset management practices that have resulted in reduced agency and road user costs
- Informing solutions for enhanced risk management practices for the planning, design, and maintenance of transport infrastructure
- Improving our 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
- NACOE's research has not only focused on economic and sustainability benefits but also on safety.
- The program has provided valuable guidance toward reducing crash risks on Queensland roads, a crucial aspect of road management. This emphasis on safety underscores NACOE's commitment to the well-being of the community.

NACOE research continued to prioritise funding to projects with clear benefits for Queensland's transport infrastructure and its management and operations.

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

CAPABILITY DEVELOPMENT

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

- Workshops that provided an 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 road map 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 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 the 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
- Published numerous reports, presentations, and papers from 2013-2023, which are available on the NACOE website
- Delivered numerous online webinars, which are published on the NACOE website and YouTube.

PROGRAM IMPLEMENTATION

An important objective of NACOE research is to facilitate the implementation of new knowledge into practice. 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. NACOE research provides synergies with Austroads findings through NACOE, ensuring that Queensland conditions and materials are fully considered. In many instances, the outputs from NACOE research have been shared with and contributed to Austroads task forces and working groups' activities, which then filter through into national documents.

Research is delivered using a range of strategic research methodologies, each one meticulously designed to ensure the highest quality of outcomes, including:

- Desktop reviews to gain an initial understanding of the research need, benefits, or application before progressing with a more in-depth study.
- Where relevant to providing confidence in the research outcomes, 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 and collaboration with industry, universities, and government bodies. The NACOE Board believes ongoing collaboration will allow TMR and the industry to leverage research and resources from other organisations, which will deliver mutually beneficial outcomes to everyone involved.

In 2021-22, NACOE worked with multiple external organisations, including:

- TThe Queensland Department of Environment and Science- in research to inform the development of technical guidelines and specifications for the use of recycled tyres and glass.
- Local Government Association of Queensland – in research to inform and develop Local Government Heavy Vehicle Route Assessment Guidelines. Central Queensland University – shared research 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 – shared research to quantify the benefit of geosynthetics for the mechanical stabilisation of subgrade materials and develop guidelines for pavement design.
- The Western Australian Road Research and Innovation Program (WARRIP) shared research on multiple collaborative projects.
- Tyre Stewardship Australia – research to facilitate the increased 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 – research to implement crumb rubber modified gap-graded asphalt.
- Australian Flexible Pavement Association (AfPA) – research to implement IC technology in 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.

NACOE

"Tony Robbins coined the saying, "If you do what you've always done, you'll get what you've always gotten", which can apply to many aspects of life and business. Given the challenges that TMR faces in providing the community with a transport network that is connected and accessible to everyone but also safe, sustainable, and supports our economy, we need our engineering practices to evolve and improve continually.

As an applied field of science, engineering is at the heart of what it means to solve those intractable problems and challenges by committing ourselves to building deep understanding, giving things a go, and learning from that experience. This is what NACOE has come to represent for us. It is a program that provides the umbrella or shelter in which to explore, take calculated risks, and try new things.

TMR and the Queensland community are the better for it, as demonstrated in some of the remarkable achievements that have been made- from the small things, like progress in the stabilisation of local pavement materials, to the more significant, like the introduction of high modulus asphalt."

Dennis Walsh
Chief Engineer (Engineering and Technology)
Queensland Department of Transport and Main Roads

Yeppen Floodplain Crossing, Bruce Highway following Ex-Tropical Cyclone Debbie.
Image Source: TMR (2017)

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PAVEMENTS

INNOVATING GREENER, SMARTER ROADS

Aerial view of contuction works Bicentennial Road interchange (looking east), Gateway Motorway North (GUN) project

Image Source: TMR (2017)

PAVEMENTS OVERVIEW

The Pavements Stream is the largest component of the NACOE program and focuses on practical and implementable research. The program comprises pavement and rehabilitation design, materials, and geotechnical solutions. It aims to introduce innovation and deliver engineering best practices across areas such as asphalt, unbound granular and stabilised pavements, surfacings, and road construction. The research strongly focuses on providing a cost-effective, resilient, sustainable road network in collaboration with industry and academia.

SIGNIFICANT OUTCOMES OF THE NACOE PAVEMENTS STREAM OVER THE LAST TEN YEARS INCLUDE:

- Introducing Enrobé à Module Élevé (EME2) high modulus asphalt and improved asphalt pavement design procedures.
- Facilitating the use of recycled materials in pavements, including reclaimed asphalt pavement (RAP), crumbed rubber sourced from end-of-life tyres, recycled glass and building waste.
- Optimising locally available granular materials through improved performance validation and evaluation guidelines.
- Informing updates to TMR specifications based on national and international best practices and research.
- Introducing new and innovative construction quality control equipment and procedures.
- Dissemination of learnings via webinars, workshops, training, technical presentations, and conference papers.

To date, over 505 projects have been delivered, and technical reports have been published on the NACOE website.

EME2 - COST EFFECTIVE ASPHALT PAVEMENTS FOR QUEENSLAND CONDITIONS

Queensland's full-depth asphalt pavements have traditionally been thicker than those in other Australian states, mainly due to the local environmental conditions.

Since the program's inception in 2013, the Pavements Stream has undertaken various research activities to improve the cost-effectiveness of asphalt pavements in Queensland, including the implementation of the 2nd generation Enrobé à Module Élevé (EME2) and the introduction of mix-specific fatigue relationships for locally manufactured asphalt mixes.

EME2 is a high-modulus structural asphalt previously developed in France that offers increased stiffness, fatigue, and rut resistance properties over conventional unmodified asphalt base course mixes. The higher stiffness and improved fatigue resistance of this mix can reduce the thickness of full-depth asphalt pavements by as much as 25%, resulting in resulting in reduced:

- Costs and construction time
- Use of scarce natural resources and lower carbon impacts

TO FACILITATE ITS BROAD-SCALE INTRODUCTION INTO QUEENSLAND, NACOE DEVELOPED:

- A procedure for the design of EME2 pavements was developed and included in the TMR Pavement Design Supplement to the Austroads Guide to Pavement Technology
- A new technical specification, MRTS32 High Modulus Asphalt (EME2), which was the first EME2 specification in Australia.

Since the first trial was undertaken by Brisbane City Council in 2014, EME2 has now been used as a pavement base layer on several significant projects in southeast Queensland, including the Gateway Upgrade North project, the Brisbane Port Access Road, Cooroy to Curra Section D, various Pacific Motorway projects, Gold Coast Light Rail, the Logan Enhancement Project, and the Bruce Highway Deception Bay Road interchange.

EME2 has also routinely been used for maintenance and rehabilitation works in South East Queensland and has become the structural asphalt base layer of choice in South East Queensland. It is now estimated that more than 3 million tonnes of EME2 asphalt have been paved across Australia, with the majority in Queensland.

The successful introduction of EME2 asphalt into Queensland is a testament to the collaborative efforts between NACOE, Austroads, Brisbane City Council, the Australian Flexible Pavement Association and local industry. This collective effort has significantly contributed to the widespread use of EME2 in Queensland.

Application of Enrobés à Module Elevé Class 2 (EME2) technology in Brisbane City Council.

Image Source: ARRB(2019)

New Deagon Deviation interchange (facing south), Gateway Upgrade North Project, March 2019.

Image Source: TMR (2019)

A NEW APPROACH TO ASPHALT PAVEMENT DESIGN

Continuing from the EME2 research, NACOE has made significant progress in optimising the design of asphalt pavements for Queensland conditions. Historically, the thickness of asphalt layers was designed using the generic fatigue relationship in Part 2 of the Austroads Guide to Pavement Technology. Following the successful completion of a multi-year study, including extensive laboratory testing, NACOE developed a procedure to facilitate the use of mix-specific modulus and fatigue relationships that can be used for pavement design. These mix-specific design procedures were published in technical note TN167: A New Approach to Asphalt Pavement Design. This approach allows designers and asphalt suppliers to optimise the design of asphalt pavements for local conditions and materials, leading to improved performance and cost-effectiveness.

NACOE also developed the first Australasian EME2-specific modulus and fatigue relationship that pavement designers can use to capitalise on the improved performance this mixed type provides over conventional asphalt mixes.

Asphalt fatigue testing

Image Source: NACOE (2020)

RESPONSIBLE USE OF RECYCLED MATERIALS

Between 2013-2023, NACOE's commitment to minimising the environmental impact of managing Queensland's transport network has yielded significant results. The Pavements Stream has undertaken extensive research to develop evidence-based solutions for using a range of different recycled materials responsibly and sustainably, including:

- The increased use of reclaimed asphalt pavements (RAP) and end-of-life vehicle tyres
- The introduction of recycled crushed glass into TMR registered asphalt mixes.

Several NACOE studies have demonstrated the significant benefits of using recycled materials in pavements. These materials can offer comparable or, in some cases, even superior structural performance to those using conventional materials, thereby reducing costs and environmental impact.

THE USE OF RECLAIMED ASPHALT PAVEMENT (RAP) IN TMR REGISTERED DENSE GRADED ASPHALT MIXES

The incorporation of RAP into new asphalt mixes has many benefits, including the reduction of cost and greenhouse gas emissions, and the conservation of natural resources such as bitumen, sand, and crushed rock.

Historically, higher percentages of RAP in TMR mixes have been limited due to equipment and technical constraints. NACOE, as a leader in the field, has played a crucial role in facilitating the increased use of RAP. NACOE investigated the variability of RAP stockpiles in South East Queensland and used the information to develop standardised procedures for incorporating varying percentages of RAP (up to 30%) in TMR registered mixes. These procedures were published in MRTS30 Asphalt Pavements and TN183 Use of High Percentages of Reclaimed Asphalt Pavement (RAP) in Dense Graded Asphalt and have since become business as usual for designing asphalt mixes with varying quantities of RAP in TMR projects.

TRANSFER OF CRUMB RUBBER MODIFIED ASPHALT AND SEALING TECHNOLOGY TO QUEENSLAND

Millions of vehicle tyres reach their end-of-life every year in Australia, posing a significant environmental concern as they mostly end up in landfills. However, the rubber obtained from these end-of-life tyres is known to improve the performance properties of bituminous binders when used in sprayed seals and asphalt layers. Crumb rubber modified (CRM) binders have been used in sprayed sealing and asphalt works in Australia and other countries for a long time but have had limited application in Queensland.

NACOE, together with Tyre Stewardship Australia and the Queensland Department of Environment and Science, undertook a multi-year project aimed at facilitating the increased use of CRM binders in sprayed seals and asphalt. The project culminated in developing the first Australian technical specification for crumb rubber modified open-graded and gap-graded asphalt mixes. The technical specification was successfully trialled on several demonstration projects in south-east Queensland.

Demonstration by Fulton Hogan, Crumb Rubber Modified Gap Graded Ashpalt Demonstration - Pimpama Jacobs Well Road City of Gold Coast.

Image Source: Courtesy of AAPA (2018)

In addition to the performance benefits of using CRMBs in sprayed seals, replacing virgin bitumen with crumb rubber binders has been shown to potentially reduce binder costs and have lower greenhouse gas emissions compared to more traditional binders. Reusing recycled tyres also lowers the demand for natural materials. To capitalise on these benefits, NACOE developed amendments to TMR's technical specifications, which changed the way the Department specified the binders used in sprayed seals.

RECYCLED CRUSHED GLASS

In 2018, the Queensland Government introduced a container refund scheme (CRS), which was expected to increase the amount of glass available for recycling. The reuse of glass in road infrastructure was identified as a possible high-value use for these materials. However, at the time, TMR only allowed for small percentages (of up to 5%) of recycled crushed glass (RCG) to be used in the lower layers of unbound granular pavements. Where possible, it is always preferable to reuse materials in their highest value application (such as asphalt pavement layers). NACOE, therefore, explored opportunities to use crushed recycled glass in TMR-registered asphalt mixes at quantities consistent with best practice. As a result, local asphalt suppliers can now use up to 2.5% and 10% crushed glass in surfacing and base course asphalt mixes, respectively.

SUSTAINABLE LOCAL MATERIALS

Optimising locally available materials is considered one of the most sustainable options when constructing and maintaining road pavements, especially in a large state like Queensland. Over the past ten years, NACOE has made significant progress in ensuring that TMR's approach to using local materials is fit for purpose and in line with best practice.

Stabilising otherwise unsuitable road construction materials is an economically and environmentally beneficial alternative to importing new materials. Approximately 15% of the state-controlled road network is stabilised with various binders, including foamed bitumen, cement and cementitious blends.

NACOE benchmarked the performance of these stabilised pavements and found that they generally perform very well and, in many cases, exceed the original service life estimates.

A 2015 economic analysis has shown that utilising a lightly bound base can lead to savings of $50 to $130 per m2 compared to a similar standard hot mix asphalt base layer, translating to savings of up to one million dollars per kilometre treated. As an outcome of this research, five new technical notes have been developed to cover the different stabilisation practices in Queensland. These notes guide practitioners regarding best practices for investigating, designing, and constructing these technologies. Using TMR as a benchmark, AustStab has moved to harmonise foam bitumen stabilisation practices and specifications across Australia.

The research, to date, revealed that increased resilience in high-exposure environments could be achieved at a fraction of the cost of full-depth asphalt when the plant-mixed cementitious modified base (CMB) and in situ mixed foamed bitumen stabilised base (FBB) are utilised per TMR specifications and design guides. Ideal conditions for CMB include moderate to heavy traffic, wet climatic conditions, non-reactive sub-grade soils and where high-quality surfacing is planned. Ideal conditions for FBB include moderate to heavy traffic volumes and various climatic conditions and sub-grade types.

The study also found that the foamed bitumen stabilisation practices adopted by the Queensland Department of Transport and Main Roads are not just effective, but also in line with best practice nationally. This alignment provides a strong foundation for our work and reassures us that we are on the right track.

Furthermore, based on this Queensland research, an Austroads national project is harmonising foam bitumen stabilisation practices across Australia. Current research has shown that a 0.5% foam bitumen application rate reduction can reduce construction costs by $20K per kilometre.

FOAMED BITUMEN STABILISATION

Previous NACOE performance monitoring studies found that granular materials stabilised with foamed bitumen are especially moisture resistant and can withstand prolonged inundation. For example, the performance of pavements treated with foamed bitumen shortly before Cyclone Debbie in early 2017 exceeded expectations and minimised reconstruction costs after this major flood event.

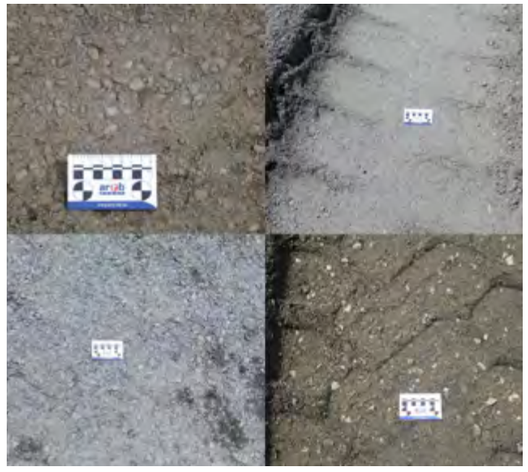
PERFORMANCE-BASED EVALUATION OF NON-STANDARD GRANULAR PAVEMENT MATERIALS

Some 20,000 km of the state-controlled road network includes unbound granular pavement layers, generally sealed with a thin bituminous surfacing. Economic and environmental considerations often encourage using locally available aggregates in the pavement layers, especially in more remote areas. In many cases, such as the Landsborough Highway in Western Queensland, these materials do not conform to standard specifications. However, in regular Western Queensland seasons, they can provide satisfactory performance when properly managed.

NACOE has been developing fit-for-purpose laboratory evaluation protocols that can be used to assess the suitability of local non-standard materials for use in different pavement applications. The testing protocols developed vary between basic index tests and more advanced laboratory testing, such as the Extra-Large Wheel Tracking Device.

Forming of upper HSG base layer using paver.

Image Source: NACOE (2018)



Basic igneous product 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right)

Image Source: NACOE (2015)

INTELLIGENT COMPACTION

Traditional road construction quality control methods lack real-time data, only cover a small portion of the constructed area, and often rely on time-consuming and cumbersome test methods. However, Intelligent Compaction (IC) technology can overcome these limitations to improve pavement construction quality and productivity.

The technology is typically used to ensure uniform and adequate compaction of earthworks and pavement layers during construction, and offers improved construction quality control and efficiency and reduced construction and maintenance costs.

If used for asphalt compaction, it uses vibrating compaction rollers equipped with an integrated compaction measurement system, a highly precise survey-grade Global Positioning System unit, and infrared temperature sensors. NACOE (in collaboration with industry, government and international partners) pioneered the implementation of IC in Queensland through the development of technical specifications and processes, undertaking several demonstration projects and providing industry training.

Some key IC demonstration projects undertaken to date include:

- Ipswich Motorway upgrade, R2D (March 2020)
- Port of Brisbane (February 2022)
- Flinders Highway (March 2023)

NACOE remains committed to pioneering progress in sustainable road construction for Queensland. We actively explore new technologies and solutions, like using geosynthetics in pavements and developing performance-based specifications and design methods, fostering industry collaboration, and sharing our knowledge to ensure safe, efficient, and environmentally friendly roads for future generations.

As Queensland's transport network evolves, NACOE will be there, paving the way for a sustainable future, one innovation at a time.

Port of Brisbane, March 2022

Image Source: Sam Afkar (2022)

AfPA Qld Award- June 2023

Image Source: Sam Afkar (2023)

Flinders Highway- March 2023

Image Source: Sam Afkar (2023)

Flinders Highway- March 2023

Image Source: Sam Afkar (2023)

Bruce Highway (Brisbane- Gympie), Gateway Motorway to Dohles Rocks Road

Image Source: Sam Afkar (2023)

02

ASSET MANAGEMENT AND HEAVY VEHICLES

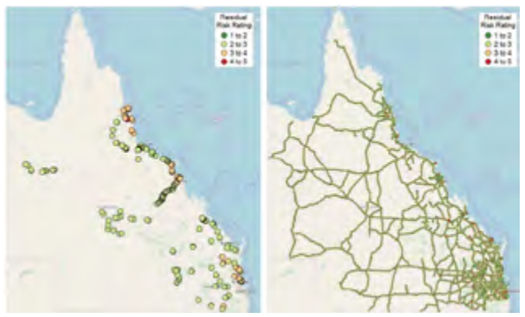
DRIVING PROSPERITY FOR QUEENSLAND

ASSET MANAGEMENT AND HEAVY VEHICLES OVERVIEW

The NACOE Asset Management and Heavy Vehicles stream has been a priority since the commencement of the NACOE research program and has focused on advancing asset management knowledge and practice. It has pursued this through improved risk assessment and evidence-based performance modelling, the underlying assumptions within these models, and their application as part of continuous business improvement.

In addition, the stream has included research into new funding strategies that explore life cycle costing implications, particularly considering the risk of extreme weather events and flooding across Queensland. The projects undertaken since NACOE's inception are listed in the following table, including completion status and links to publications—several other projects produced outputs for the sole purpose of guiding TMR and remain unpublished.

- **A4** Accounting for Life Cycle Costing Implications and Network Performance Risks of Rain and Flood Events
- **A5** Incorporating Uncertainty in PMS Modelling
- Implementation of Skid Resistance Management Plan (SRMP), Including Knowledge Transfer (Training)
- **A6** Implementation of Skid Resistance Management Plan (SRMP), Including Knowledge Transfer (Training)
- Incorporation of the Pavement Risk Score into the Pavement Condition Index
- **A20** Improved Model to Predict the Remaining Life of Sprayed Seal Surface
- Incorporation of the Pavement Risk Score into the Pavement Condition Index
- **A27** Harmonisation of Pavement Impact Assessment: Updates and Extended Marginal Cost Values
- **A28** Investigate and Compare Life Cycle Cost / Benefits and Performance of Line Marking and Delineation
- **A34** Customer-Based Level of Service in Road Maintenance
- **A35** Identification of Residual Risk for each Element and Development of a Funding Allocation Methodology for Elements
- **A44** Synthesis and Dissemination of Best Practice, Value for Money Asset Preservation Solutions and Strategies Based on NACOE and Other National Programs
- **R103** Virtual weigh-in-motion and Queensland freight movement study
- **R61** Investigating the use of Telematics to Deliver Messages to Drivers (Heavy Vehicles)
- **R56** Mobile Mapping Solutions for Heavy Vehicles
- **R20** Heavy vehicle Interception Site Guideline and Audit- TN115
- Local Government Heavy Vehicle Route Assessment Guidelines
- **S1** Measurement of Bridge- Vehicle Interaction Under Live Load
- **R5** Vehicle to Infrastructure Technology Applications in Queensland



Map of Queensland showing the location of the residual risk sites with coloured risk ratings used in A35, A44: Innovation in Residual Risk Models

Image Source: TMR (2019)

A35, A44: INNOVATION IN RESIDUAL RISK MODELS

The NACOE Asset Management stream focuses on advancing asset management knowledge and practice. It has pursued this through improved risk assessment, evidence-based performance modelling, and the underlying assumptions within the models, which are applied as part of continuous business improvement.

More robust risk assessment methodologies and asset management tools and models allow the Queensland Department of Transport and Main Roads (TMR) to apply the right treatment in the right place at the right time. Better prioritisation of maintenance and rehabilitation spending through more informed, risk-based decision-making means a better result for all Queensland road users.

Between 2017 and 2021, NACOE Project A35 developed and put into operation two residual risk frameworks- the pavement residual risk model (PRRM) and the structures residual risk model (SRRM). These residual risk models were based on an analytical hierarchical process. The PRRM comprises five risk dimensions, each built up from risk indicators. There are now 13 risk indicators in total.

The PRRM framework

The PRRM framework consists of two components; the calculation database and the visualisation of the results. All pavement residual risk (PRR) score calculations can be undertaken and stored in a master file linked to a visualisation tool built for the project. A series of charts and maps can be used to visualise the PRR score results at state-wide, district, and individual road levels.

A forward life-cycle analysis was also undertaken to predict the change in risk, which allowed the effect of the maintenance budget to be considered and, therefore, the consequence on the risk of different budget funding levels over a life cycle. A review of PRR weightings' impact on the risk indicators and dimensions was undertaken to assess their influence on the PRR score. In particular, the effect of maintenance funding on the pavement condition index and regulation compliance risk indicators and their impact on the final PRR score was examined.

This showed that each district's average PRR score was 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 needed to be balanced against the Queensland Department of Transport and Main Roads (TMR) 's risk appetite.

The SRRM framework

The development of the SRRM framework, risk indicators, and risk dimensions was also undertaken. The SRRM considers 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. The model has 12 contributing risk indicators. A dataset and the visualisation framework were developed with preliminary weightings in place.

The following steps were to operationalise the SRRM and PRRM by a trial review of TMR's priority routes and finalising the framework for another residual risk model, the network operations residual risk model. Once operational, TMR staff were shown how to use the PRRM and SRRM.

The technical dissemination focused on developing an Excel-based workflow that provided users with instructions on creating and using both the PRRM and SRRM. This included a description of each risk indicator, data sources, risk dimensions, and weights for each indicator and risk dimension.

In addition, the technical dissemination for NACOE A35 included a webinar that provided an overview of the project and described the development of the PRRM and SRRM.

A4: LIFE CYCLE COSTING

NACOE's Asset Management stream has also delivered benefits to the Queensland Department of Transport and Main Roads (TMR) through the life cycle costing of asset management strategies. A key focus has been improving the road network's resilience to rain and flood events with a limited budget and against increasing climatic threats.

From 2013-2016, NACOE Project A4 examined the catastrophic effect on the Queensland road network of the 2010-2013 flood events, which resulted in between 23% and 62% of the TMR state-controlled network closed or with limited access through the summers in these years.

It was determined that pavement management, maintenance, and rehabilitation practices needed to be reviewed to decrease exposure to damage cost-effectively. The NACOE project modelled alternative life cycle costing implications to determine this. Compared to reflecting actual events, two alternative options were examined, namely:

» **Option 1:** A fully resilient road modelled to increase life-cycle costs over the seven case study links by $146.5 million, with very high agency costs not sufficiently offset by reduced road user costs. This approach may be best suited to the most heavily trafficked roads, where closures and repair works typically come at an extremely high economic cost and should be avoided.

» **Option 2:** A more proactive, progressive 'stitch-in-time' rehabilitation program is estimated to deliver a net life-cycle cost savings of $596 million. A small increase in agency costs is more than compensated for by reduced road user costs due to a more resilient network.

The rural highway network, particularly critical inland routes, may require this small increase in funding. However, this will deliver value-for-money treatments through a more progressive program of work, avoiding the 'boom-and-bust' cycle.

Brisbane Flood Aerial View of Homes Under Water in Australia's Worst Flooding Disaster.

Image Source: Shutterstock 99706355

Aerial View Rocklea Markets and Light Industrial Area.

Image Source: Shutterstock 99706388

The project found Option 1 equated to a marginal benefit-cost ratio (MBCR) of approximately 0.9, i.e. a small net loss. For Option 2, there was a MBCR of 6.9. That means one extra dollar of agency spending on this selection of roads returns nearly seven times that in road user cost savings. For a best-for-network strategy, which selects the option that maximises net benefits, the MBCR is approximately 3.7.

The analysis also highlighted the importance of treating pavements within their target life before accelerated deterioration starts. Based on the outcomes of the project, several recommendations were made:

» To review and update relative funding of various road and maintenance activities by road type and environment

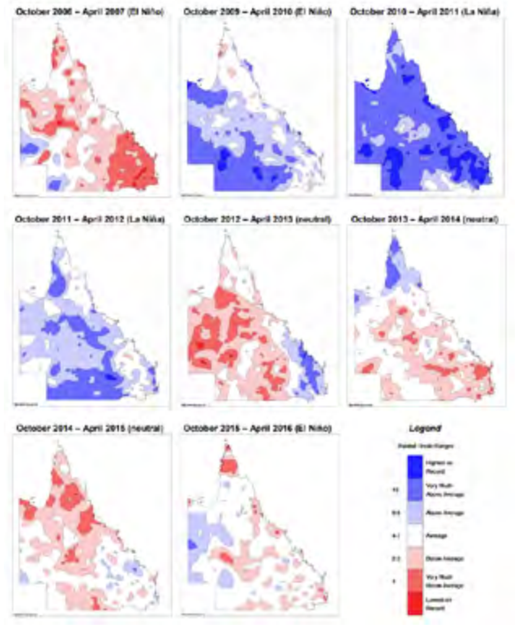
» To consider options for more flexible and responsive funding models

» To develop and encourage relevant programs for accelerated funding of overdue rehabilitation works To explore enhanced climate and flood modelling in planning

» To drive more substantial consideration of route-based investment prioritisation

» To share these findings with the Queensland Treasury, other state and territory road agencies, and the Commonwealth to demonstrate a strategic approach to improving network resilience

» To consider integrating the findings of different case studies into international activities and provide an opportunity for comparisons relating to economic, social and environmental challenges.



Rainfall deciles from October to April in select years (blue above average, red below average).

Image Source: Bureau of Meteorology (2016)

Man saving his dog during a Queensland flood.

Image Source: Shmelly50 (2024)

INNOVATIVE ROAD ASSESSMENT TOOL EMPOWERS FAIRER COST RECOVERY FOR QUEENSLAND

NACOE has taken a significant step towards fairer road maintenance cost recovery by developing the Guide to Traffic Impact Assessment (GTIA).

This guideline, published in 2017, replaces the outdated "Guidelines for Assessment of Road Impacts of Development" (GARID). It empowers TMR to hold heavy freight industries accountable for the wear and tear they inflict on state-controlled roads.

Traditionally, quantifying heavy freight vehicles' disproportionate impact on road deterioration and recovering associated costs from industry has been a challenge. The GTIA introduces the marginal cost (MC) concept, representing the additional cost of TMR due to the impact of specific developments, such as heavy freight projects. This cost is calculated based on factors like Traffic Speed Deflectometer (TSD) data and Long-Term Pavement Performance (LTPP) models.

By implementing the GTIA and the MC framework, TMR can now accurately assess the impact of heavy freight traffic on specific road sections, calculate the associated cost of this impact based on objective data, and hold the industry accountable by requiring them to contribute financially to offset pavement damage caused by their activities.

This approach offers several benefits. It ensures that heavy freight industries contribute their fair share towards road maintenance, reducing the burden on taxpayers. By recovering costs from the sector, TMR can invest more resources in maintaining and upgrading roads, benefiting all road users.

The GTIA also encourages responsible transportation practices by incentivising road-friendly vehicles and technologies.

The GTIA represents a significant advancement in Queensland's road management. By introducing an objective and data-driven system for cost recovery, TMR can ensure a fairer, more sustainable approach to maintaining the state's vital road network.

Park Ridge Connector. Trucks travelling on multi-lane roadway.

Image Source: TMR (2011)

Park Ridge Connector. Trucks using dual carriageway in the Logan city area.

Image Source: TMR (2011)

LOCAL GOVERNMENT HEAVY VEHICLE ROUTE ASSESSMENT GUIDELINES: ENSURING A SAFER, MORE EFFICIENT QUEENSLAND TRANSPORT NETWORK

Since their introduction in 2017, the Local Government Heavy Vehicle Route Assessment Guidelines (LGVHRAG) have played a pivotal role in transforming Queensland's freight transport landscape. Developed by ARRB in collaboration with the Local Government Association of Queensland (LGAQ), these guidelines have demonstrably improved the safety, efficiency, and sustainability of heavy vehicle access to local government (LG) roads. Before the LGVHRAG, assessing the suitability of heavy vehicle routes lacked a standardised approach. This posed challenges for both LG road managers and the freight industry. The LGVHRAG addressed this gap by providing a comprehensive framework for route assessment.

Barcaldine- Aramac Road, rehabilitate and widen 2021

Image Source: TMR (2021)

KEY SUCCESSES:

- **Enhanced Safety:** The LGVHRAG emphasises crucial factors like geometric performance, road safety implications, and structural capacities. This data-driven approach ensures that LG roads can safely accommodate appropriate heavy vehicle traffic, minimising the risk of accidents for all road users.
- **Improved Efficiency:** Streamlined route assessments facilitated by the LGVHRAG empower LGs to make informed decisions regarding heavy vehicle access. This reduces unnecessary delays for the freight industry, optimising transport efficiency.
- **Risk-Based Decision Making:** The guidelines incorporate a robust risk assessment process. This allows LGs to grant access even when some route aspects fall outside the ideal parameters, provided effective mitigation measures are implemented. This flexibility fosters a practical and collaborative approach to managing heavy vehicle access.
- **Expanded Guidance:** Since their initial publication, the LGVHRAG has been continuously updated to reflect evolving industry practices and address emerging challenges. Notably, the guidelines now encompass:
  - Low-speed or constrained environments are often encountered in urban areas.
  - Low-speed, low-volume rural roads are a prevalent feature of Queensland's vast road network.
  - Unsealed roads require specific considerations for heavy vehicle access.
- **Collaboration and Knowledge Sharing:** The LGVHRAG actively promotes collaboration between LGs, the freight industry, and road management bodies. This fosters a knowledge-sharing environment, ensuring consistent and effective implementation of the guidelines across the state.

Looking to the future, the LGVHRAG remains a cornerstone for safe and efficient heavy vehicle access on Queensland's LG roads. As the transport landscape evolves, these guidelines will continue to be refined to ensure the Queensland freight network's sustainable and prosperous future.

A46: IMPROVED MODELS FOR ASSESSING THE COST OF MAINTENANCE

Another notable project, A46, focused on enhancing the understanding and management of deferred maintenance and renewal. The objectives were clear: refine the knowledge of deferred maintenance, facilitate stakeholder communication, and improve budgeting activities. Through meticulous research and collaboration, the project achieved remarkable insights.

THE REPORT FOCUSED ON FIVE CASE STUDIES RELATED TO CURRENT TMR PRACTICES, WHICH INCLUDED:

1. Pavement structural condition assessment and modelling
2. Sensitivity of pavement structural condition to external influences
3. Consideration of whole-of-life cycle costs associated with routine maintenance expenditure
4. Sprayed seal surfacing performance
5. Consideration of economic optimum intervention levels for pavements.

Through these case studies, NACOE identified opportunities for improvement by adopting low-cost rehabilitation treatments for road pavements. Key lessons emerged, emphasising the need for consistent structural metrics, comprehensive cost considerations, and continuous improvement actions. The recommendations advocate for flexibility in treatment approaches, seizing "easy wins," and strategically prioritising identified opportunities. This critical research has informed how TMR and other road agencies can optimise their essential maintenance by enhancing models, optimising data utilisation, leveraging technology, and conducting further research.

This holistic approach optimises cost performance, mitigates risks, and ensures sustainable infrastructure management. By implementing these recommendations, NACOE continues demonstrating its commitment to excellence in asset management, providing safer and more efficient road networks for all Queenslanders.

Heavy Vehicle Driving Along Rural Queensland Road.
Image Source: ARRB (2013)

Park Ridge Connector. Trucks Using Dual Carriageway in the Logan City Area.
Image Source: TMR

A68: UNDERSTANDING THE PAVEMENT IMPACTS OF LOW AND ZERO-EMISSION HEAVY VEHICLES

In a collaborative research effort across multiple NACOE streams, including asset modelling, future vehicles, freight, and pavements, NACOE project A68, was developed to assess the potential pavement impacts that the heavier low—and zero-emission (LZE) vehicles will have on the road infrastructure network.

THIS PROJECT AIMED TO:

- Develop and apply estimates of the future freight task, including the migration to LZE vehicles, with a range of forecast scenarios from low to very high uptake, including for different locations in the state
- Understand the resultant pavement impacts, including a review of the state of knowledge on pavement impact models (for vertical and horizontal loading) and the evidence base considering the configurations that apply now and in the future
- Undertake a preliminary assessment of the agency costs for several scenarios and recommendations for further research.

Austroads has also shown interest in the work and has commissioned the development of a pavement modelling analytical framework, data specification, and case studies for application by member agencies.

Australian road train on regional sprayed seal road.

Image Source: Shutterstock 558511807

A44: KNOWLEDGE TRANSFER FOR THE BETTERMENT OF OUR NETWORK

One of NACOE's key strategic objectives is facilitating ongoing development by disseminating learning to the industry and the regions.

The project "Synthesis and dissemination of best practice asset preservation solutions and management strategies for sealed roads" was undertaken to answer a need within the Queensland Department of Transport and Main Roads (TMR) to increase awareness and application of best practice technical and asset management solutions.

THE A44 PROJECT COVERED:

- A review of challenges and opportunities related to increasing awareness within TMR. The information was based on information gathered during visits to TMR Districts as part of the Queensland Road System Performance Plan (QRSPP) review process.
- Creating a set of customised information sessions for TMR staff. The information sessions were undertaken as webinars during June/July 2020. The materials and recordings of the webinar were provided to TMR for internal distribution only.

The project reviewed information from each TMR District to determine the chosen topics for dissemination. Information on topics was collected as part of previous NACOE projects. The review of topics revealed the following themes:

- Asset management
- Traffic Speed Deflectometer
- Line-marking
- Drainage
- Stabilisation
- Automated crack detection
- Seals

The list of topics was reviewed with TMR, and the following information sessions were selected:

- Road network resilience – the effect of extreme flood events
- Asset management costs and pavement impact assessment
- Developing road user levels of service
- Construction of pavements in expansive soils
- Improved line-marking for wet areas
- Improving the pavement management system
- Skid resistance update

Seven webinars, each lasting 60 to 90 minutes, were organised. The webinars drew more than 800 participants. Presentation slides and recordings of the webinars were provided to TMR to make available through its intranet, ensuring TMR staff had access to this information beyond the live webinars. Feedback collected from the webinars showed that participants considered the content of the webinars valuable and relevant and wanted more training and information sessions on these topics.

Webinar	Viewed	Registered
Road Network Resilience	237	130
Asset Management Costs and Pavement Impact Assessment	198	121
Improved Line-Marking for Wet Areas	188	110
Construction of Pavement in Expansive Soils	190	112
Improving the Pavement Management System	176	111
Developing Road User Levels of Service	191	119
Skid Resistance Update	260	107

03

ROAD SAFETY

DELIVERING SAFER JOURNEYS

ROAD SAFETY OVERVIEW

Safety is paramount in Queensland's transport network. Over the past decade, the NACOE Road Safety stream has exemplified this commitment. Dedicated to safeguarding every road user across every journey, we've identified and employed innovative technologies and proactive strategies.

NACOE'S ROAD SAFETY SUBPROGRAM HAS SOUGHT TO DELIVER BENEFITS TO THE NETWORK IN SEVERAL WAYS BETWEEN 2013 -2023, INCLUDING:

- Reducing crash risk at roadworks sites
- Protecting the public at short-term roadworks sites
- Identifying effective traffic control devices
- Proactive approach to roadside safety
- Wide centreline effectiveness evaluation
- Researching high-risk crashes
- Streamlining traffic management
- Investigating new and emerging technology solutions in road safety
- Automating data collection for risk assessment models

MAJOR ROAD SAFETY-RELATED PROJECTS AND RESULTING PUBLICATIONS BETWEEN 2013 - 2023 INCLUDE:

- **R54** Automated collection of AusRAP road attributes using DVR and Pattern Recognition Techniques
- **R56** Mobile Mapping Solutions for Heavy Vehicles
- **R70** Addressing Road and Safety Barriers at Bridge Approaches
- **R73** W-beam Guard Rail Under-run: Development of Treatment Warrant Guidelines
- **R85** Review of Engineering Treatments for Urban Fringe Environments
- **R87** Development of Crash Reduction Factors
- **R98** Development of Speed Management Activities Guideline
- **R99** Identification of Safety Risk and Development of Mitigating Treatments for Narrow (4 m) Sealed Roads
- **R104** Benefits achieved by major infrastructure projects in the study area of Bruce Highway
- **R106** Identify traffic control devices to reduce the likelihood of safety incidents involving members of the public at short-term roadwork sites.

NACOE

10 YEAR HIGHLIGHTS REPORT 2013 – 2023

TACKLING HIGH-RISK CRASHES IN QUEENSLAND

NACOE research helped Queensland tackle the challenge of head-on, run-off-road, and intersection crashes causing severe injuries and fatalities on its roads. To combat this critical issue, NACOE determined the factors behind these crashes and identified effective countermeasures.

NACOE'S RESEARCH EXPOSED SEVERAL CRUCIAL INSIGHTS:

- **High Proportion of Serious Injuries:** A staggering 40% of all injury crashes on Queensland roads resulted in severe or fatal outcomes.
- **Head-On Crashes - A Cause for Concern:** While representing only 4% of all crashes, head-on collisions were responsible for a disproportionate 6% of fatalities on state-controlled roads.
- **Young Drivers at Risk:** The study found that young drivers (aged 17-24) were significantly overrepresented in these high-severity crashes.
- **Roadway Factors Play a Role:** The condition of the road and curves were identified as contributing factors, highlighting the importance of proper maintenance and infrastructure design.

NACOE's extensive research identified various road hazards and proposed practical and effective solutions to mitigate them. Solutions included implementing strategic road markings, such as broader centre lines with audible warnings, to reduce head-on and cross-median collisions. Additionally, median barriers and 2+1 lane configurations can physically prevent head-on crashes and reduce the severity of cross-median incidents.

To further increase road safety, enhancing signage and road markings and implementing advisory speed signs, especially on curves, can guide drivers and encourage safer speeds. Maintaining road surface quality, particularly on high-risk curves, is crucial for driver control and reducing crash risk. Implementing safer roadside design features like safety barriers, removing roadside hazards, and managing slopes can decrease the impact of potential run-off-road incidents. Finally, sealing, widening, and improving the edges of road shoulders can provide a safer space for drivers to regain control if they veer off the road and thus potentially preventing run-off-road and head-on crashes into oncoming traffic.

By implementing the solutions identified in this NACOE research and pursuing further investigations, Queensland has significantly reduced the number of severe and fatal crashes, making its roads safer for everyone.

100km Speed Limit Signage on Australian Motorways.
Image Source: ARRB (2015)

Wire Rope Safety Barrier System on Australian Road.
Image Source: NACOE (2021)

IMPLEMENTING IN-ROAD TECHNOLOGY SOLUTIONS

Technology is capable of playing an important role in road safety. Through its road safety stream, NACOE has been researching various methods of employing technology to reduce crash risk on the TMR road network. Two important NACOE projects looked at the potential to automate data collection for risk assessment models and reduce the risk of crashes at short-term roadworks sites.

AUTOMATING DATA COLLECTION FOR RISK ASSESSMENT MODELS

For improved road safety, TMR routinely undertakes proactive risk assessment of the road network for the identification and treatment of high-risk sections, thereby reducing the crash risk on the network. The risk assessment models used include the Australian Road Assessment Program (AusRAP) and the Australian National Risk Assessment Model (ANRAM). These models require the collection of more than 50 road attributes and roadside features at 100m intervals. Systems for collecting road condition data for these purposes are labour-intensive and prone to error.

CAN WE PARTIALLY OR FULLY AUTOMATE THE DATA COLLECTION PROCESS?

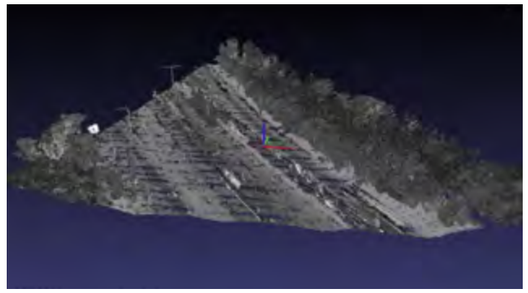
If so, then this has the potential to provide the most up-to-date and reliable data sets needed for the timely assessment of the road network, improving road infrastructure and reducing fatalities and severe injuries on the roads.

NACOE, in collaboration with Central Queensland University, decided to investigate. NACOE's R54 project aimed to develop and evaluate deep learning neural network–based methods for automating the extraction of road attributes, especially those required by AusRAP road safety risk assessment models. The automatic collection of road attributes from video data using machine learning techniques and cross-validation with other data sources has the potential to provide a range of value-added products for road condition, safety, environmental and improved obstacle clearance estimates.

Sixty-one models (one for each attribute) and nine functions were developed to detect AusRAP attributes from video files and associated metadata. The individual models were evaluated using training, testing, and misclassification errors.

BASED ON THE CASE STUDY, THE ATTRIBUTES THAT CAN BE DETECTED WITH HIGH ACCURACY AT THE 10M LEVEL INCLUDE:

- Delineation
- Road signs
- Chevron alignment markers
- Poles/posts
- Line markings
- Traffic signals at intersections
- Metal safety barriers.



Sample MLS data

Image Source: NACOE (2019)

Attributes: road, line, metal barrier and tree (left: original image, right: recognition result)

Image Source: NACOE (2019)

R106: REDUCING CRASH RISK AT ROADWORKS SITES

Short-term roadworks sites are a significant area of concern for safety. Interactions between road users, road workers, plants, and vehicles at roadworks sites can result in fatal crash events.

In 2020, NACOE project R106 sought to provide insight into why near misses and crashes involving the general public occur, specifically at short-term roadwork sites. The project aimed to identify potential safety improvements to existing and new practices, alternative traffic management opportunities, and supporting traffic control devices to proactively reduce the risk of crashes occurring at short-term roadwork sites.

A trial was held, testing various traffic control devices at short-term roadworks sites on the Pacific Motorway at the Gold Coast and using CCTV cameras to monitor speed and driver compliance.

THE FOLLOWING TRAFFIC CONTROL DEVICES WERE SELECTED TO BE TRIALLED:

- Video surveillance signage (using a Variable Message Sign or VMS)
- Speed radar sign ('smiley' sign) in combination with the video surveillance VMS.

The video surveillance signage would lead drivers to believe that video surveillance was actively recording driver behaviour (speeds).

This was performed using a VMS, which showed the messages 'Road Safety Camera' and 'Check Speed'. The presence of the CCTV cameras employed for speed monitoring fulfilled the notion that it would indeed be possible to collect vehicle speeds for enforcement purposes. This project used the "smiley" speed radar sign as a speed feedback radar sign.

Overall, it was proved that both the VMS and VMS + Smiley traffic control devices effectively improved speed limit compliance, as the mean and 85th percentile speeds were reduced.

For the control tests, over 95% of the vehicles travelled at least 10 km/h above the speed limit. The combined effect of the VMS+Smiley traffic control device was the most successful at lowering speeds. The combined effect of the VMS+Smiley traffic control device was the most successful at lowering speeds.

R7: BRUCE HIGHWAY WIDE CENTRELINE EFFECTIVENESS EVALUATION

The Bruce Highway is a crucial transportation route in Queensland, serving as the primary north-south freight and commuter corridor, connecting various coastal population centres from Brisbane to Cairns over 1,673km. It plays a vital role in the National. Land Transport Network links west-east freight networks, connecting resource sectors, inland agriculture production areas, and coastal ports while also serving as a major tourism route.

But it has been consistently one of the most dangerous roads in the nation, both in terms of total crashes and total fatal and serious injury (FSI) crashes – indeed, from 2005-09, crashes on the Bruce Highway contributed to 61% of deaths on the Queensland network. The Bruce Highway Action Plan is a Queensland Government initiative to improve the operation and safety performance of the Bruce Highway, and one component was the targeted installation of wide centrelines and wire rope barriers.

NACOE delivered a project that monitored and evaluated the relative performance of these treatments over several years. A pre-curser to subsequent examinations into the effectiveness of various wide centre lane treatments, this NACOE project found that wide centrelines can be expected to reduce overall FSI crashes by approximately 22% and cross-centreline FSI crashes (including head-on crashes) by roughly 43%.

This road safety improvement reduces crash risk and severity and provides financial benefits to the Queensland communities along the Bruce Highway. An estimate of the Bruce Highway identified a financial improvement as high as $150 million per year if extended along the entire highway.

NACOE research has also focused on identifying high-risk crash types and locations along the Bruce Highway. A combination of treatments is expected to deliver further significant savings and, most importantly, reductions to the road toll.

Wide centrelines on the Bruce Highway

Image Source: TMR (2015)

A PROACTIVE APPROACH TO MOTORCYCLE ROADSIDE SAFETY IN QUEENSLAND

Unfortunately, motorcycle crashes are a significant concern in Queensland, with a worrying rise in fatalities and injuries in recent years.

Fortunately, the Queensland Road Safety Strategy and Action Plan prioritise efforts to reduce crash severity and occurrence, emphasising the "Safe System" approach. This approach acknowledges human error while aiming to create a forgiving road system that minimises road trauma.

THE ROLE OF MOTORCYCLE PROTECTION SYSTEMS (MPS)

One crucial aspect of this strategy involves mitigating the severity of motorcycle crashes by reducing the impact with roadside objects. This can be achieved through:

- Eliminating roadside objects known to commonly cause serious harm to motorcyclists.
- Creating traversable roadsides.
- Utilising road user protection systems to shield riders from obstacles, steep embankments, and other infrastructure.

Previously, the approach to MPS implementation was primarily reactive, focusing on locations with a history of motorcycle crashes (Black Spots). This reactive approach could not proactively address high-risk locations on a broader scale. Recognising the limitations of the reactive approach, NACOE aimed to develop a proactive, warrant-based system for identifying locations where MPS installation would be most beneficial. This system would also guide the layout design and MPS length for optimal effectiveness.

Throughout the project, researchers considered several factors contributing to motorcycle run-off-road crashes, including:

- **Road attributes:** These attributes were aligned with existing frameworks, such as the Dutch decision tree, AusRAP risk factors, and motorcycle run-off-road Risk Score.
- **Historical motorcycle run-off-road crash sites:** This data provided valuable insights into past incidents.

Using these factors, a quantitative scoring system was developed. This system identified high-risk locations across the network based on a specific set of criteria. Notably, the score utilised readily accessible data from various sources like DVRs, Google Earth, and ARMIS, enabling desktop assessments for greenfield and brownfield designs.

The proactive approach offers several significant benefits, including early identification of high-risk locations. This allows for preventive measures like MPS installation, potentially saving lives and reducing injuries. Additionally, the system relies on objective data, ensuring a consistent and evidence-based approach to MPS deployment and data-driven decision-making. Lastly, this research helps improve resource allocation by focusing on high-risk areas where resources can be efficiently allocated, maximising the impact of MPS implementation.

The project resulted in comprehensive technical guidance for MPS implementation, including a clear definition of MPS, a decision tree process to guide MPS installation, prioritisation for strategic deployment, and guidance for determining the layout and length of MPS required for various scenarios, such as single curves or a series of curves.

This project represents a significant step forward in proactively protecting motorcyclists on Queensland roads. The developed system and technical guidance empower authorities to make data-driven decisions regarding MPS installation, ultimately leading to a safer road environment.

R2: NACOE STREAMLINES TRAFFIC MANAGEMENT IN QUEENSLAND

NACOE has worked on a project to formalise Queensland supplements for the Austroads Guide to Traffic Management. This project aimed to streamline practices, promote consistency, and improve safety for workers and road users. The Austroads Guide to Traffic Management is Australia's national benchmark for traffic management practices.

However, some Queensland-specific requirements and best practices go beyond the scope of the national guides. To address this gap, the Queensland supplements were developed to complement the Austroads Guide to Traffic Management with additional guidance tailored to the state's specific needs. These supplements cover local context and considerations, regulatory requirements, best practices and recommendations.

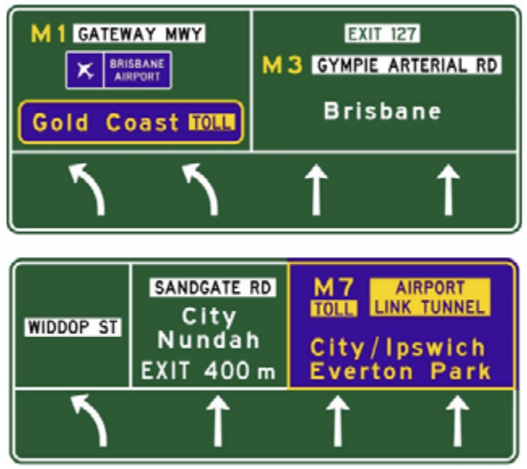
Formalising these supplements offers several benefits, including enhanced consistency, more precise guidance, and improved communication between stakeholders involved in roadwork projects.

NACOE played a vital role in this project by collaborating with TMR and industry stakeholders, facilitating workshops and consultations, and developing a comprehensive and user-friendly document outlining the formalised Queensland supplements.

The formalisation of Queensland supplements for the Austroads Guide to Traffic Management represents a significant step forward in ensuring safe and efficient traffic management practices across the state. NACOE remains committed to supporting TMR in its ongoing efforts to improve road safety and enhance the overall experience for road users in Queensland.

It is essential to note that the formalised Queensland supplements should be used with the Austroads Guide to Traffic Management for safe and effective traffic management practices in Queensland.

Large road sign located near to the Brisbane Botanic Gardens- Queensland, Australia.
Image Source: Jacob_D (2018)



Examples of overhead lane designation style direction signs
Image Source: TMR (2020)

04

STRUCTURES

BUILDING FOR RELIABILITY AND RESILIENCE

STRUCTURES OVERVIEW

NACOE has provided an opportunity to harness the combined bridge and structural engineering expertise of TMR and ARRB to undertake complex assessments and trials. The knowledge gained has provided TMR with a better understanding of its bridge assets' health and promoted NACOE nationally as a hub for bridge research and investigation.

MAJOR STRUCTURE-RELATED PROJECTS AND RESULTING PUBLICATIONS BETWEEN 2013 - 2023 INCLUDE:

- **S1** Measurement of Bridge-Vehicle Interaction Under Live Load
- **S2** Guidelines for Monitoring of Existing Structures
- **S3** Deck Unit Bridge Deck Analysis Under Live Load
- **S6** Review of Bridge Asset Management System-Structures Inspection Manual
- **S15** Long-term performance of FRP replacement components and structures
- **S19** Geopolymer Concrete Performance Review
- **S26** Virtual WiM – Enriching WiM and Enhancing Decisions
- **S28** Review of Performance of Concrete Pipe Culverts
- **S29** AS/ISO 13822 Framing Investigation into the Assessment of Deck Unit Bridge and Transverse Stressing Bar Deficiencies
- **S31** In-line Timber Bridge Replacement Options
- **S41** Precast Geopolymer Concrete Elements
- **S43** Improving Structures Asset Management Capability Systems
- **S47** Impact of Corrosion Inhibitor Admixtures on Durability of Concrete
- **S51** Suitability of the Use of Recycled Aggregate in Concrete
- **S61** Optimisation of Accelerated Curing Processes for PSC and the Associated Material Performance Issues
- **S62** Management of Structures with Concrete Halving Joint–Scale Model Testing
- **R103** Virtual weigh-in-motion and Queensland freight movement study
- **O17** Investigation of Factors Affecting Fish Passage in Culverts: Development of Precast or Prefabricated Box Culvert Design Concept for Fish Passage

Image Source: ARRB (2019)

OVER THE PAST TEN YEARS, PROJECTS THROUGH THE NACOE STRUCTURES STREAM HAVE BENEFITTED QUEENSLAND'S TRANSPORT INFRASTRUCTURE NETWORK. THESE BENEFITS INCLUDE:

- 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
- A better understanding of the capacity and performance of load-limited and critical bridges
- Enhanced quality of repair practices, with better 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
- 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 work procedure to replace transverse stressing bars (TSB) in deck unit bridges.
- An improved bridge-jacking methodology and process
- A TMR training and learning platform in strategic asset management that will be used by a broad range of stakeholders, including non-TMR entities such as local governments
- Shared and expanded knowledge across 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
  - Prioritisation of maintenance and rehabilitation
  - TMR's existing jacking monitoring system for bridge lifting
  - Factors that affect risk scores and risk score anomalies

Image Source: ARRB (2019)

S63: MANAGEMENT OF STRUCTURES WITH CONCRETE HALVING JOINT-SCALE MODEL TESTING PROJECT

In 2021, NACOE set out to understand the behaviour and capacity of the bridges with concrete halving joints. New TMR bridge designs do not allow halving joints (HJ). Still, legacy structures will likely remain for many years, so their behaviour and issues must be comprehensively understood. A bridge with halving joints consists of suspended spans with dapped ends supported on the nibs of abutments or adjacent cantilevered girders. The physical configuration of the joint introduces a sudden change in geometry, resulting in significant variations in the stiffness and strength within the joint section. Reduced cross-section stiffness and strength, combined with complex localised bending and shear, makes HJ vulnerable to failure, often exacerbated by other factors.

Reinforced and post-tensioned, suspended spans and T-Roff girders are particularly interesting to TMR. Year one of this project reviewed international research and best practices in managing concrete halving joint bridges. The investigation found that significant research has been undertaken since the early 1960s regarding the performance and capacity of halving joints, with notable failures that have occurred and driven research and investment into their investigation and assessment. The UK standard CS 466: Risk Management and Structural Assessment of Concrete Half-joint Deck Structures currently represents a best practice management approach, indicating TMR is aligned with other jurisdictions in adopting the CS 466 methodology.

In the project's second year, the utilisation of nonlinear finite element modelling significantly advanced the comprehension of half-joint structural behaviour. The project report detailed the relevant findings and identified gaps, including post-tensioning effects, development length (particularly prestressed strand), fatigue, and corrosion issues affecting the HJ behaviour and capacity. Continued investigations with the finite element model developed and experimental tests may provide further insights into this area.

The underside of a new reinforced concrete bridge across the Pioneer River at Mackay, Queensland, showing pylons and beams reducing in size.
Image Source: IngeBlessas Shutterstock (2024)

S51: 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, the widespread adoption of concrete has not been realised. For example, recycled concrete aggregate (RCA) has been identified as suitable for partial replacement of up to 30 per cent 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).

This project aimed to determine whether recycled aggregates, including RCA, RCG, RA, FNS and BA, can 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, 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). Two additional 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, durability, availability, and cost of materials.

The performance of concrete mixes that utilise recycled aggregates for replacing the 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.

A literature review indicated that at high replacement levels (50% up to 100% by mass), coarse or fine RCA concrete would likely 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, RCA concrete's workability, strength, and durability properties are likely 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. Including recycled aggregates in concrete can create environmental and social benefits by deverting material from landfills and reducing the need to produce new aggregate material. The research replacement level findings indicated that this can be achieved without penalty to the performance of the N-Class (non-structural) concrete applications in the scope of this review.

Upon completion of this project, TMR updated Technical Specification MRTS70 to permit 20% RCA as coarse aggregate and/or 20% RCG as fine aggregate.

Concrete Drain Pipes stacked
Image Source: Shutterstock (2024)

S59: DETECTING LOAD CAPACITY DETERIORATION IN BRIDGE DECK UNITS USING STRUCTURAL MONITORING

Around 40% of TMR's 3,300 bridges and major culvert assets have superstructures based on transversely stressed prestressed precast concrete deck units. A significant number of bridges also have substructures which include prestressed precast concrete piles. A TMR bridge inspection database review found that cracking in these components (deck units and piles) could be attributed to some form of alkali-silica reaction (ASR) deterioration. Given that these structures represent a significant portion of the asset base, NACOE researched to quantify better the expected impacts on the long-term operational future of the bridges.

The research involved a thorough literature review on the impacts of ASR deterioration on the structural capacity of prestressed and reinforced concrete structures. The investigation also considered how TMR's Bridge Inspection System (BIS) and Structures Inspection Manual (SIM) could be harnessed to improve reporting and prevent ASR deterioration. Direct investigation through visual inspection and physical testing also took place at several sites across the network. Static chord elastic moduli measured through core testing for the deck unit samples were calculated based on the measured compressive strengths at the lower bound of the expected range. This is typical of concrete undergoing ASR deterioration, whereby softness initially reduces more significantly than compressive strength. Split tensile strengths were at the upper bound of the expected range calculated based on the measured compressive strengths. This was unexpected, but tensile strength would likely reduce as the ASR deterioration progressed.

The project has demonstrated that by investigating the material properties of ASR-affected structural members, in combination with their effects on structural behaviour and failure modes, and applying some mitigating treatments or rehabilitation, structures with mild to medium levels of ASR deterioration can be appropriately managed and remain in service.

Image Source: ARRB (2019)

S64: AIR BLAST SAFE PRACTICES DURING CONSTRUCTION

Safe construction of transport infrastructure is an essential consideration for TMR. Learning from international cases, modern air blast construction methods and resulting ground vibrations can generate unintended consequences and threaten people, property, and project timelines.

Research is vital to develop methods that protect communities, prevent costly damage, and keep projects on track. By minimising these disruptions, we ensure construction benefits society without causing unnecessary harm.

To ensure TMR's ongoing high-quality working knowledge in this critical area is up-to-date, NACOE was enlisted to revise and update TMR technical note TN03 published in 2013 by undertaking an extensive literature review on existing guidelines, a gap analysis on TN03 and field testing to verify the proposed recommendations.

The literature review covered several local and international guidelines based on British Standard BS7350 or German Standard DIN4150. It also discussed the prescriptions of the Queensland Environmental Protection Act 1994 Section 440ZB. Additionally, NACOE has considered industry stakeholder feedback and reviewed the current guidelines, standards, and best practices for ground vibration and air blast safety during construction.

By understanding these essential construction methods, NACOE supports TMR in ensuring safe working practices when delivering key state infrastructure.

S57: BUILDING FLOOD RESILIENCE IN QUEENSLAND'S BRIDGES

Over the past ten years, there has been a notable increase in flood damage to bridge approaches on the Queensland transport network. This has resulted in service disruptions, particularly when continuity and accessibility are essential for post-flood recovery and community resilience. This project was initiated to explore opportunities for more resilient bridge approaches by learning from experience and improving current practice.

In the past four years, this project has identified and investigated bridges across Queensland's network to find common themes and patterns representing the entire inventory of bridges and their conditions as managed by TMR. By investigating these case studies' hydraulic and geotechnical attributes, causes of scour and their influencing factors were identified.

THE ANALYSIS WAS PERFORMED BASED ON TWO RISK SCORES:

1. The embankment risk score and

2. The network risk score, with the final risk score calculated by combining the two elements.

Informed by these findings, the Structures team developed a risk assessment tool to identify the bridges most at risk of scour at the embankments and on the highest priority parts of the network.

Most recently, this ongoing project has completed a proof-of-concept of the risk assessment tool for a pilot district, analysing 204 bridges in the Darling Downs District. The early successes resulting from this work have led to an extension of the analysis of the entire 2,468 bridges in the TMR network. This research has demonstrated that the tool can identify bridges with a confirmed history of scour, assisting the ongoing identification of items of interest supporting TMR in building resilience and safety across the Queensland transport network.

S26: KEEPING QUEENSLAND'S BRIDGES SAFE AND EFFICIENT.

The Queensland Department of Transport and Main Roads (TMR) maintains a vast network of bridges across the state. To ensure longevity and safety, TMR embarked on a project to optimise heavy vehicle access management using Weigh-in-Motion (WiM) technology.

TMR manages over 33,000 kilometres of roads and three thousand bridges, facilitating the movement of heavy vehicles crucial to the Queensland economy. However, excessive weight loads can compromise bridge integrity and safety. Traditional methods of monitoring heavy vehicle weights were resource-intensive and limited in scope. This NACOE project investigated the feasibility and value of using WiM technology to quantify and manage heavy vehicle loads on bridges, enhance decision-making regarding heavy vehicle network access and bridge management, and focus on larger vehicles like low loaders, load platforms, and mobile cranes. The project team analysed existing WiM and classifier data to identify and address inconsistencies and improve data quality and accuracy. Further, the team developed filters to isolate data specific to the vehicles of interest and benchmark WiM records for enhanced confidence in the data.

THESE EFFORTS ENABLED THE CREATION OF THE FOLLOWING INSIGHTS:

1. A comprehensive understanding of load platforms and low loaders operating throughout Queensland.

2. Mobile crane movement patterns at specific locations.

3. A deeper understanding of traffic patterns at individual bridge sites.

By leveraging WiM technology and improving data quality, the project provided TMR with more credible data for informed decision-making related to heavy vehicle access and bridge management and enhanced network safety through better control of heavy vehicle loads. These insights will also improve bridge asset management by identifying potential load-related maintenance needs.

The project also identified opportunities for further development of virtual WiM (vWiM) technology, paving the way for even more efficient and effective heavy vehicle management in the future. By harnessing the power of WiM technology, NACOE is helping TMR maintain a sustainable and resilient road network for generations to come.

Image Source: Shutterstock (2024)

S32: TRANSVERSE STRESSING BAR REPLACEMENT TECHNIQUES

Approximately 40% of TMR's bridge stock is deck unit (DU) bridges. Transverse stressing bars (TSB) are a critical structural component of DU bridges. However, a reliable method to quantify damage to TSB and its impacts on bridge performance is not currently available. There is also a lack of a consistent approach to rectify TSB damage, including TSB replacement statewide. Non-destructive testing (NDT) technologies have been trialled, but mixed results have been reported. This project undertook a study into the implementation of NDT technologies in the condition assessment of TSBs on DU bridges through a review of available literature and the NDT trials conducted by TMR.

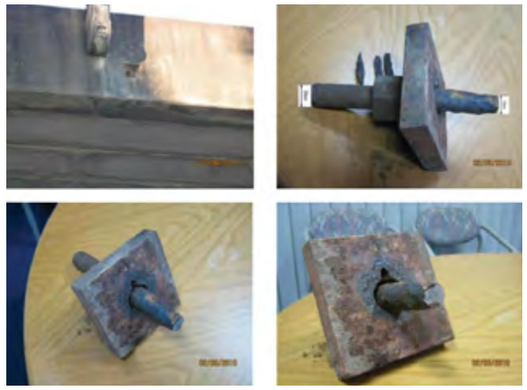
The project also reviewed the current practice of replacing TSB on DU bridges to formalise current TMR TSB replacement procedures. The review of the current trials of NDT undertaken by TMR reveals that the trialled NDT is ineffective in detecting defects in existing TSBs. The vendors of different systems have not been able to demonstrate that the various technologies trialled have a sufficient level of accuracy and reliability. It was recommended that none of the trial technologies be considered for routine use in assessing the condition of TSBs within the TMR bridge stock.

Further technological improvements are required for selected technologies to demonstrate the reliability and quality of the output. A draft technical specification has been prepared based on the findings of this project to provide practitioners with a works method statement and procedure for the effective removal and replacement of defective TSBs on TMR deck unit bridges.

This NACOE project provided knowledge on the effectiveness and applicability of currently available non-destructive testing technologies in assessing the condition of transverse stressing bars on TMR deck unit bridges.

It also demonstrated that the various technologies trialled have insufficient accuracy and reliability. None of the trial technologies should be considered for routine assessment of the condition of TSBs within the TMR bridge stock.

The findings from this NACOE project have informed the current best practice in removing and replacing transverse stressing bars and have developed a standard method statement and technical specifications for removing damaged transverse stressing bars on deck unit bridges.



Broken sections of TSB on Bridge ID 7330 (Jun 2010 L2 inspection)

Image Source: NACOE (2019)

End 1 stress bar broken, Bridge ID 625 (Oct 2016 L2 inspection)

Image Source: NACOE (2019)

S61: OPTIMISING ACCELERATED CURING PROCESSES FOR PRECAST CONCRETE

In 2021, NACOE invested resources researching accelerated curing processes for precast prestressed and reinforced concrete bridge components. This initiative tackles a critical challenge in modern construction- balancing the need for faster production cycles with concrete infrastructure's long-term performance and durability.

Traditional curing methods, while well-established, may not be ideal for the large-scale, complex concrete elements used in bridges today. While accelerated curing offers a potential solution, concerns exist regarding its impact on long-term performance. This project aimed to address these concerns and identify opportunities for improvement.

The project began with a comprehensive review of current TMR practices and a comparison with methods employed by other state road agencies. This was complemented by a thorough examination of existing research on the potential effects of accelerated curing on concrete performance. Additionally, the project team built upon the previous TMR laboratory testing from scoping studies. A series of laboratory tests formed the core of the investigation. Concrete cylinder specimens were cast, cured using six different regimes, and then rigorously tested.

These regimes included three accelerated methods, a standard seven-day moist cure for comparison, and a dry/no curing control. The testing, conducted per TMR's Technical Specification MRTS70, yielded valuable insights. The results indicated that TMR's current accelerated curing requirement of 420°C.h and a minimum temperature of 50°C could be slightly adjusted, provided minimum strength requirements are met. This flexibility can refine curing processes without compromising strength or durability.

Compared to the standard seven-day moist cure, this approach compensates for any potential strength or durability reductions associated with accelerated curing. This observation aligns with findings from previous studies, suggesting that high-strength concretes (particularly those formulated with blended cement) exhibit minimal sensitivity to curing regimes regarding chloride penetration, a key durability indicator..

OPTIMISING FOR LONG-TERM PERFORMANCE

The project's findings suggest that, as long as the concrete mix design adheres to TMR's MRTS70 specification for the designated exposure classification, potential reductions in strength and durability due to accelerated curing may not be a significant concern for TMR's precast/prestressed concretes. This project has yielded valuable insights with the potential to inform the development of future accelerated curing specifications. The research report details the findings and proposes further research areas to delve deeper into the relationship between accelerated curing and concrete durability, building upon the strong foundation established by this project.

This project contributes to a more efficient construction industry while ensuring the durability of Queensland's bridges. The project also identified further research areas to delve deeper into the relationship between accelerated curing and concrete durability, building upon the strong foundation established by this project.

Approaches to the new reinforced concrete bridge over the Pioneer River at Mackay, Queensland.

Image Source: IngeBlessas Shutterstock (2024)

05

SUSTAINABILITY

GREENER ROADS, BRIGHTER FUTURE

SUSTAINABILITY OVERVIEW

The Sustainability stream represents the NACOE program's commitment to environmental concerns. Since 2013, the NACOE program has invested significantly and dedicated numerous projects to identify, research, and share environmentally sustainable innovations and best practices for constructing, maintaining, and operating transport infrastructure.

SEVERAL AREAS OF NOTE INCLUDE:

- Environmental resilience and incorporating bushfire impact into road design.
- Identification and testing of non-traditional, such as locally occurring materials
- Optimising the use of sustainable stabilised pavements
- Increasing the range of options for recycled materials in road construction
- Working with industry to facilitate the development of specifications that enable new and improved technologies.
- Improved characterisation of asphalts in Queensland enabled the introduction of new asphalts for thinner pavements, which, following NACOE research, have also been introduced into national specifications.
- Enhancing the use of recycled materials in unbound and stabilised products
- Investigating the WHS and environmental impacts of recycled and novel materials
- Characterisation of bituminous products to enable increased use of recycled crumb rubber.
- Assessing the potential greenhouse gas emissions reductions and sustainability benefits of innovative pavement solutions.

MAJOR SUSTAINABILITY-RELATED PROJECTS AND RESULTING PUBLICATIONS BETWEEN 2013 - 2023 INCLUDE:

- **A4** Accounting for Life-cycle Costing Implications and Network Performance Risks of Rain and Flood Events
- **O10** Implementing the International Climate Change Adaption Framework for Road Infrastructure in Queensland. Climate Change Adaption Framework for TMR
- **O17** Investigation of Factors Affecting Fish Passage in Culverts: Development of Precast or Prefabricated Box Culvert Design Concept for Fish Passage
- **O21** Dispersive and Slaking Soils Management
- **O24** Using Recycled Materials in Stabilised Pavements
- **O25** Use of Recycled Materials in Earthworks and Drainage
- **O26** Framework to Incorporate Bushfire Resilience into Road Infrastructure
- **P30** Use of Bagasse Ash and Fibres in Pavement Construction
- **P31** Transfer of Crumb Rubber Modified Asphalt and Sealing Technology to Queensland
- **P34** Performance-based Evaluation Protocol for Non-standard Granular Pavement Materials
- **P39** Long-life Pavement Alternatives for Queensland
- **P49** Quantifying the Benefits of Geosynthetics for the Mechanical Stabilisation of Subgrade Soils: An Interim Design Approach
- **S51** Suitability of the Use of Recycled Aggregate in Concrete
- **P57** Implementing the Use of Reclaimed Asphalt Pavement (RAP) in TMR- Registered Dense-graded Asphalt Mixes
- **P75** Transferring Crumb Rubber Modified Gap-graded Asphalt Technology to Queensland
- **P76** The Use of Recycled Glass in Pavements
- **P94** Optimising the Use of Recycled Materials in Queensland for Unbound and Stabilised Products
- **P106** Assessing the Potential Greenhouse Gas Emissions Reductions and Sustainability Benefits of Innovative Pavement Solutions
- **P116** Recycled Materials in Roads; QLD State of Play
- **P117** Developing A Pavement Sustainability Assessment Tool for Queensland

O26: DESIGNING FOR RESILIENCE: INCORPORATING BUSHFIRE IMPACTS INTO ROAD DESIGN

Australia's recent bushfire crisis has laid bare the critical role road infrastructure plays in all aspects of bushfire management, from prevention and preparation to response and recovery. However, these same fires exposed the vulnerability of roads and travellers facing these devastating events. Increased frequency of extreme weather events is expected to increase the frequency and intensity of bushfires further, necessitating a proactive approach to safeguarding our road networks.

To address this challenge, a collaboration between the National Asset Centre of Excellence (NACOE) and the Western Australian Road Research and Innovation Program (WARRIP) has delivered a comprehensive framework to incorporate bushfire resilience into road infrastructure. Published in 2023, this framework provides transport agencies with practical guidance on integrating bushfire prevention, preparedness, response, and recovery (PPRR) throughout the entire life cycle of road infrastructure projects.

The NACOE/WARRIP framework identifies bushfires' diverse impacts on road infrastructure, from direct damage to hindering evacuation and emergency services. Recognising the shared responsibility for bushfire management, the framework emphasises collaboration between various stakeholders, including government agencies, utility providers, and local communities.

The PPRR model is a well-established approach to managing risk and was central to the research's approach toward guiding road agencies through each infrastructure development and management stage. The PPRR findings included:

- **Prevention:** Strategically managing roadside vegetation by minimising the potential for bushfire ignition along roads.
- **Preparedness:** Conduct risk assessments to identify vulnerable areas and critical infrastructure, ensure clear emergency access routes, and collaborate with emergency services to develop response plans.
- **Response:** Implementing measures to protect road users during bushfires, such as temporary closures, signage, and providing real-time information.
- **Recovery:** Expediting the repair and restoration of damaged roads to facilitate recovery efforts and restore vital community connections

Australian bushfires: burnt eucalyptus tree along the road. Road sign is twisted by the heat of the bushfire

Image Source: Daria Nipot (2020)

Taking a detailed approach to address bushfire management, NACOE and WARRIP researchers considered input factors and adapted strategies according to the unique context of each project, including the location, road type, and available budget. It highlighted the benefits of a unified approach involving all relevant stakeholders in decision-making and implementation. The framework emphasised balancing bushfire prevention measures with sustainable solutions and consultation with relevant stakeholders. Additionally, the framework aims to inform the coordinators of bushfire management strategies with other agencies within infrastructure within the road corridor, such as utility providers.

This comprehensive framework informs transport agencies about building resilience against bushfires into their transport infrastructure. Through proactive planning, collaboration, and strategic implementation, transport infrastructure operations for communities facing these challenging events can be significantly improved.

P2, P14, P16: NEW LEARNINGS FOR SUSTAINABLE STABILISED PAVEMENTS

Queensland's extreme climate events present regular challenges when building and maintaining the vast network of Queensland roads. Road materials need to be able to withstand temperature and moisture impacts, including flooding. Traditional road construction methods are increasingly challenged to withstand these climate impacts and increasing traffic loads. Premature deterioration and expensive repairs can sometimes result. There is an increased need to select climate-resilient solutions, focus on using recycled materials, and reduce reliance on non-renewable resources. Identifying an opportunity to address these challenges, NACOE embarked on a multi-year research project to improve the use of foamed bitumen stabilised pavements, including exploring the feasibility of using different recycled material blends as host materials for both foamed bitumen stabilised and cement stabilised pavements. The goal was to improve the range of suitable road construction methods and support the best use of recycled materials toward sustainable solutions to overcome these environmental challenges.

Stabilisation involves treating unbound road pavement materials with additives like cement or bitumen to improve their strength, durability, and overall performance. Project O24 evaluated the performance and mechanical properties of a range of recycled host material blends treated by stabilisation techniques through mix design evaluation with laboratory testing. The research produced new mixes that could be used as effective base and subbase materials, reducing the need for expensive imported materials.

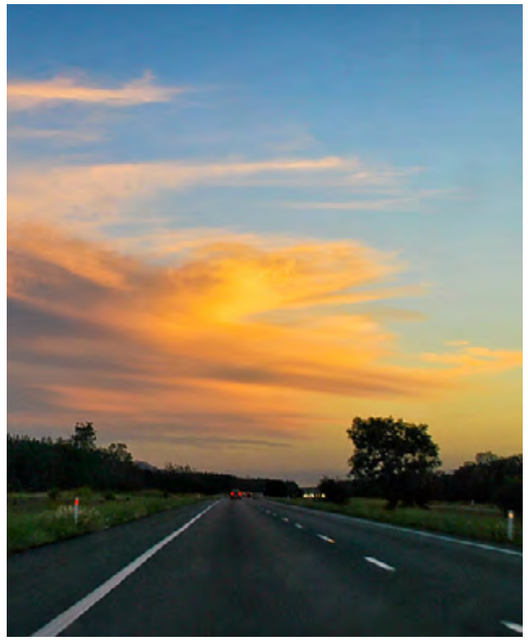
THE PROJECT FOCUSED ON TWO COMMONLY USED STABILISATION TECHNOLOGIES IN QUEENSLAND:

» **Plant-mixed cementitious modified base (PM-CMB):** This involves mixing cement with crushed rock in a factory before transporting it to the construction site.

» **In situ mixed foamed bitumen stabilised (I-FBS) base:** This method involves injecting foamed bitumen directly into the existing road materials on-site, creating a more robust and stable base.

The research team conducted a comprehensive evaluation of these technologies, which included reviewing national and international best practices; this involved comparing Queensland's practices with established methods used worldwide to identify areas for improvement.

Researchers also analysed the performance of existing Queensland roads built using PM-CMB and I-FBS to assess their effectiveness and longevity and investigated factors affecting performance. They studied factors like traffic volume, climate, and subgrade conditions to understand how they influence the performance of stabilised pavements, comparing the costs of using stabilised materials with traditional methods like full-depth asphalt to determine the economic benefits.



Sunset over Queensland Highway

Image Source: Lory Noya (2018)

THE PROJECT FINDINGS INCLUDED:

» Queensland's practices were benchmarked to national and international standards for mixing and construction binder selection and application, and structural design.

» Most existing PM-CMB and I-FBS pavements (over 93%) were in good to excellent condition, exceeding their original design life. This highlighted the effectiveness and durability of these technologies.

» Stabilisation offered significant cost savings when compared to full-depth asphalt options. Using PM-CMB and I-FBS could lead to savings of up to 85% and 78%, respectively.

This vital research has significantly impacted road construction practices in Queensland. NACOE produced five new technical notes outlining best practices for investigating, designing, and constructing stabilised pavements. These notes provide valuable guidance to practitioners and ensure consistency in project execution. Using TMR as a benchmark, NACOE collaborated with industry stakeholders to harmonise with foam bitumen stabilisation practices and specifications across Australia. Based on the research findings, the widespread adoption of stabilised pavements is projected to significantly reduce TMR construction and maintenance expenditures.

Multiple NACOE research projects on stabilisation have addressed immediate challenges of road construction in Queensland and paved the way for a more sustainable future. By promoting the use of locally available materials and reducing the need for transportation, this project contributes to a more environmentally friendly approach to road infrastructure development. The success of the "Stabilisation Practices in Queensland" project demonstrates NACOE's commitment to continuous innovation and improvement in the road construction industry. The research program continues to explore various aspects of road asset management, aiming to deliver cost-effective, sustainable, and resilient solutions for Queensland's transportation network.

Spray Sealed Road, Rural Queensland

Image Source: ARRB (2018)

Winding Queensland Road

Image Source: ARRB (2018)

INCREASED USE OF RECYCLED MATERIALS IN ROAD CONSTRUCTION

Driven by a commitment to sustainability and economic efficiency, NACOE research has given confidence in using a wide range of recycled materials in road construction. This approach conserves virgin resources and creates valuable opportunities to use byproducts and waste materials effectively. Sustainability is a core consideration throughout many of NACOE's research projects. As such, the program has taken a multi-faceted approach to the challenge, exploring the development and feasibility of innovative new technology and the viability of implementation.

EXPLORING THE POTENTIAL OF NON-STANDARD AND MARGINAL MATERIALS

The state-controlled road network in Queensland predominantly consists of unbound or lightly bound granular pavement layers with a thin bituminous surfacing. Non-standard pavement materials, often marginal or locally sourced materials, may not adhere to standard specifications. Still, where suitable resources are available, they can perform well if selected, constructed and managed appropriately. These materials are often the best solution for generating "low carbon emissions" pavement solutions for projects as they require minimal transport and low energy demand in production. They are either unbound or only lightly bound with high emissions cementitious or bituminous binders.

Developing a performance-based evaluation protocol for non-standard granular pavement materials is another significant step towards sustainable road construction. This approach explores the potential of readily available local materials, particularly in western Queensland's regions, where arid conditions and lower traffic volume areas prevail. In 2021-22, TMR funded the creation of a GIS map and database of TMR technical reports that identify and provide details of historic non-standard pavement materials. This will inform potential correlations between material types and sources with ongoing performance, loading, and climate events, enhancing the accessibility and utility of the existing data to inform current and future material use and research.

Adding more non-standard pavement and materials reports to the TMR GIS database will facilitate better decision-making and research in selecting and applying locally available materials, considering economic and environmental factors.

By creating a GIS database of historical projects and conducting further research, the project aims to make informed decisions about selecting and applying these locally sourced materials, considering economic and environmental factors.

Several studies and reports conducted by NACOE and other jurisdictions have documented these materials' sources, treatments, and performance in both regional Queensland and Australia.

Queensland Coastal Road

Image Source: Lory Noya (2018)

P76: EXPANDING THE USE OF RECYCLED GLASS IN ROADS

NACOE has also investigated the feasibility of increasing the allowable proportion of recycled crushed glass (RCG) in road pavements. This initiative addresses the growing challenge of glass waste management and explores the potential of using RCG in higher-value applications, such as granular base courses and asphalt layers. Around 150 million tonnes of glass packaging are consumed annually globally, with only 690 kilotonnes recycled.

In November 2018, the Queensland Government introduced a container refund scheme (CRS) to increase the amount of glass available for recycling. Reusing glass in road infrastructure is a high-value use for these materials. Some road jurisdictions in Australia and internationally already allow for limited amounts of recycled crushed glass (RCG) in the structural and surfacing layers of pavement. This vital research aimed to investigate the feasibility of increasing the allowable proportion of RCG permitted in granular pavement layers and asphalt layers to provide a high-value use of RCG in Queensland.

Asphalt surface courses with 10% RCG by mass were found to perform in-service and conventional asphalt mixes, although based on limited studies. Initial laboratory testing during this project also suggested that up to 5% RCG can be successfully incorporated into a typical TMR asphalt mix.
Future work will include additional laboratory testing on mixes containing a range of RCG to characterise the engineering properties and performance in a typical TMR asphalt mix. This will also help improve the TMR RCG specification.

Glass particles for recycling in a machine in a recycling facility.

Image Source: Belish (2024)

Brisbane skyline viewed from Highgate Hill

Image Source: Maythee Voran (2024)

sat4p

SUSTAINABILITY ASSESSMENT TOOL FOR PAVEMENTS

ASSESSING THE POTENTIAL GREENHOUSE GAS EMISSIONS REDUCTIONS OF INNOVATIVE PAVEMENT SOLUTIONS

Sustainability is an important consideration in selecting a road construction and maintenance solution, along with other considerations such as value for money, local supply opportunities/constraints, traffic impacts, project risk, future maintenance options reducing rework, and ensuring quality and long-term performance for the site conditions.

NACOE project P106 explored the assessment of the greenhouse gas (GHG) emissions reductions and sustainability benefits of a range of innovative pavement solutions researched by NACOE and others researched across the Western Australian Road Research and Innovation Program (WARRIP) and Austroads program.

This project also uses the findings of the Sustainability Assessment Tool (SAT) under NACOE / WARRIP project P117.

This project investigated a range of typical pavement inputs and designs for urban and rural roads, including typical designs and maintenance treatments, to better understand the opportunities for analysis using the SAT tool.

Some of the innovative pavement technologies were assessed included high modulus asphalt (EME2), crumb rubber modified binder (CRMB) for sprayed seals, crumb rubber modified (open-graded) asphalt (CRMA), foam bitumen stabilised (FBS) base with a sprayed seal, dense-graded asphalt (DGA) with reclaimed asphalt pavement (RAP), marginal and non-standard material (MM) with a sprayed seal, dense-graded warm-mix asphalt (WMA), recycled crushed concrete (RCC) in a in dense-graded asphalt (DGA), recycled crushed glass (RCG) in a standard granular base and dense-graded asphalt (DGA), and foamed bitumen stabilised (FBS) base with a sprayed crumb-rubber modified binder (CRMB) seal.

These innovative materials were used in the alternative pavement designs and modelled against the base case using a standard pavement. A range of pavement designs were modelled across the entire life cycle, including the use phase, construction phase, maintenance phase, disposal, transport to site, and off-site.

The research findings identified innovative pavement solutions that were investigated and presented various sustainability benefits and cost impacts.

In addition to the emissions modelling, a cost-benefit analysis was undertaken for each pavement design, including the total net present value (NPV) and NPV of carbon emissions at a 7% discount rate and $31.36/tonne CO2-e cost of carbon.

Based on the assumption, the results of this assessment showed that for rural pavement designs, the most significant life cycle cost savings were seen for higher traffic roads, and for urban pavement designs, the greatest life cycle cost savings were achieved for the use of EME2, associated with a substantial reduction in thickness (60 mm) that was achieved.

Sprayed seal application to repair cracking on roads.
Source: NACOE (2021)

07

NETWORK OPERATIONS

DATA-DRIVEN SOLUTIONS FOR SMARTER ROADS

NETWORK OPERATIONS OVERVIEW

Since its inception, NACOE's Network Operations stream has consistently delivered a substantial return on investment through benefits to TMR and the Queensland transport network. For a decade, this future-focused research team has identified network best practices globally and applied them to Queensland roads to optimise how we use and understand our road network.

SEVERAL AREAS OF NOTE INCLUDING BUT NOT LIMITED TO:

- **R2:** Formalise Queensland Supplements for the Austroads Guide to Traffic Management- (TRUM)
- **R20:** Heavy vehicle interception site guideline and audit- TN115
- **R22:** Measuring On-Road Congestion Costs for Multi-Modal Travel- Case Study 2: Bruce Highway Managed Motorway Project
- **R34:** Evaluation of In-Service Compliance for Road-Friendly Suspensions Using Emerging Technologies
- **R46:** Review of TMR Guidance for Head-On, Run-off-Road and Intersection Crashes in Queensland
- **R47:** Measuring excessive congestion costs for freeways and arterials by using multiple data sources
- **R61:** Investigating the use of Telematics to Deliver Messages to Drivers (Heavy Vehicles)
- **R76:** Development of Hybrid Data Model Prototype for Enhanced Cost of Congestion Methodology
- **R77:** Realtime determination of spare capacity of routes for enhanced management of congested road network
- **R103:** Virtual weigh-in-motion and Queensland freight movement study
- **R108:** Review of Road Operations Intervention Levels
- **R113:** Energy Reduction Opportunities for Road Operations Infrastructure
- **O14:** Critical review of design and development practices that relate to access for people with a disability (universal access)
- **O17:** Investigation of Factors Affecting Fish Passage in Culverts

Image: Intersection in Brisbane Queensland Australia
Source: ARRB (2018)

R76: HYBRID DATA MODEL FOR THE ENHANCED COST OF CONGESTION (COC) METHODOLOGY

The Queensland Department of Transport and Main Roads (TMR) aimed to develop an automated system for reporting the Cost of Congestion (CoC) across a network of roads under various jurisdictions.

This three-year project sought to address the limitations of using individual data sources by creating a hybrid data model that combines data from detection loops, Bluetooth devices, and probe vehicles. This innovative approach aimed to provide a more comprehensive and accurate picture of network performance.

A hybrid data model that combines data from various sources, such as detection loops, Bluetooth devices, and probe vehicles, is considered the most comprehensive data source. This project aimed to develop a web-based analysis and visualisation software prototype to test the quality and performance of hybrid data 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, conducted the enhanced CoC calculation and reporting at the link, route, and network levels.
- **Year Two** 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 its main applications.

The project utilised datasets and a prototype web software to investigate the behaviour of data from different sources, including hybrid data, detection loops (STREAMS), probe data (HERE), and Bluetooth in the City of Gold Coast.

The study found that using hybrid data improved the data coverage of STREAMS from 62% to 85%. The hybrid speed data captured the speed profile characteristics from other data sources for freeway and motorway links. Additionally, the hybrid speed value moderates 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 provide users with greater confidence in quality, accuracy, and coverage compared to other individual speed data sources.

The project aimed to showcase the function and capability of 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. The results of the case studies suggested that hybrid data, which improved data coverage, captured the key speed profile characteristics of individual data sources, and mitigated the volatility and variability of some raw data, was better than STREAMS data alone.

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 were tested and enhanced to a satisfactory level to support a scalable roll-out of hybrid data to a broader scope. The research findings suggested expanding the hybrid data to serve broader TMR road networks, using the knowledge gained to support more case studies, project evaluation, and incident impact analysis at the link, route, and network levels, and incorporating travel time reliability cost as the next step in the prototype upgrade using the datasets developed for the Gold Coast network.

R77: REAL-TIME DETERMINATION OF SPARE CAPACITY OF ROUTES FOR ENHANCED MANAGEMENT OF CONGESTED ROAD NETWORKS

Traffic congestion is a persistent challenge in urban areas. NACOE aimed to develop a real-time system for determining spare capacity on roads, which is the difference between a road's theoretical capacity (design or operational) and its actual traffic volume. Knowing spare capacity in real-time allows for improved traffic management strategies, such as:

» Providing more accurate travel information to drivers.

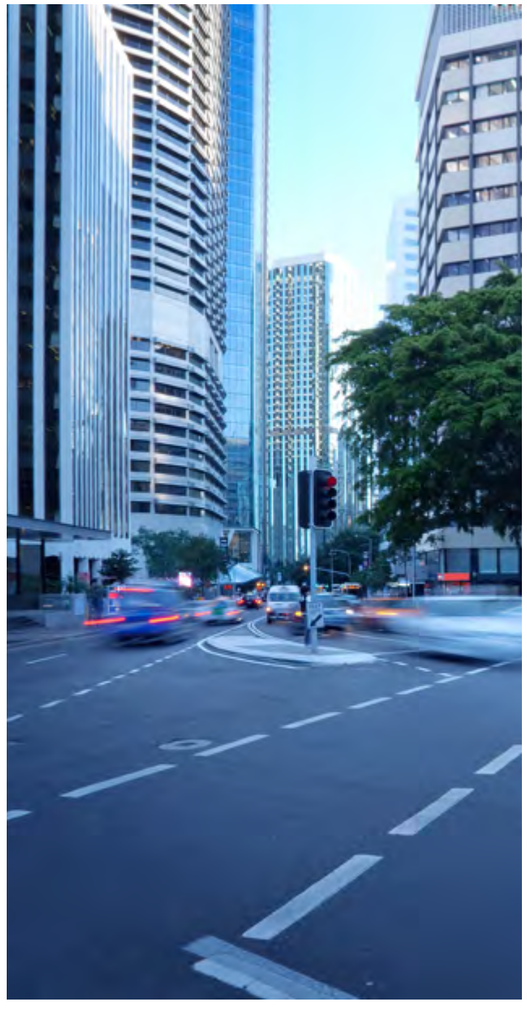
» Optimising traffic signal control systems.

Knowledge of spare capacity in real-time has led to enhanced traffic management strategies, such as providing more accurate traveller information and the potential to manage better/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. This prototype was calibrated and validated via a case study comprising 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 and 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 a 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 peak hours, but it did not identify off-peak hours as expected. This finding suggests that the prototype is reasonably accurate in establishing saturated traffic conditions in real-time.



Brisbane City Street

Source: Shutterstock 116619862

R104: BENEFITS ACHIEVED BY MAJOR INFRASTRUCTURE PROJECTS ON THE BRUCE HIGHWAY

This multi-year study investigated the effectiveness of smart motorway treatments and major infrastructure projects on the Bruce Highway's southbound lanes and the broader road network. By analysing the "before-and-after" effects of these interventions, the project aimed to:

» Assess the impact of smart motorway treatments (ramp metering, variable speed limits, and queue detection) on congestion.

» Evaluate the potential benefits of major infrastructure projects like the Boundary Road interchange upgrade, Gateway Upgrade North (GUN), and Redcliffe Peninsula Rail Line (RPRL).

» Inform future investment decisions and benchmark the Bruce Highway's performance.

This project allowed NACOE to gain a better understanding of how the cost of traffic congestion on the Bruce Highway has changed over the past five years due to a range of smart motorway treatments and major infrastructure projects. The study aimed to evaluate the effectiveness of various treatments and assess the potential impacts of the infrastructure projects on the performance of the Bruce Highway southbound (citybound) and the broader road network. This study's results helped determine the effectiveness of past investments, inform future investments and benchmark performance.

Four major infrastructure projects relevant to the Bruce Highway or response strategies were identified for benefit evaluations- ramp metering, variable speed limit (VSL) and automatic queue detection and queue protection (QPQD) systems; Boundary Road interchange; Gateway Upgrade North (GUN); and Redcliffe Peninsula Rail Line (RPRL).

THIS STUDY COVERED TWO PARTS:

» **Part One:** Bruce Highway traffic performance evaluation: Focus on the before-and-after comparison for Bruce Highway southbound to assess individually the impacts of the first three projects listed above.

» **Part Two:** Travel choice changes investigation: investigate how the infrastructure works influenced mode choice and impact on Bruce Highway and the broader road network, mainly focused on evaluating RPRL and GUN projects.

THE BENEFITS AND IMPACT OF THE FOUR MAJOR INFRASTRUCTURE PROJECTS ARE SUMMARISED AS FOLLOWS:

» **1. Ramp metering, VSL and QDQP systems:** It was observed from the data that the most significant improvement occurred when all Smart Motorway treatments (ramp metering, VSL and QDQP) were activated. The before-and-after comparison (2015 versus 2017) revealed significant congestion reduction on Bruce Highway. While there was still ongoing traffic disruption from the GUN project, after-period data revealed a 21 per cent reduction in normalised excessive delay cost and a 23 per cent reduction in both normalised reliability cost and total cost. QDQP added significant benefits to a decrease in Bruce Highway congestion. Implementing ramp metering, VSL, and QDQP systems also increased Bruce Highway's operational capacity before the flow breakdown and maintained a higher capacity after the flow breakdown.

» **2. Boundary Road interchange upgrade:** Boundary Road interchange upgrade: A significant reduction in motorway congestion cost was observed from a before-and-after comparison (2016 versus 2018) for the links directly impacted by the upgrade. While the average weekday peak period VKT increased by three per cent, the normalised high delay cost, reliability cost and total cost were reduced by 55 per cent, 45 per cent, and 47 per cent, respectively. However, due to the overlapping of project time frames, a portion of the reduction in congestion cost should be attributed to the benefits of ramp metering, VSL and QDQP systems.

» **3. Gateway Upgrade North (GUN):** The completion of the GUN project led to an operational capacity improvement, attracted a significant increase in demand for the Bruce Highway southbound and at the same time eased the peak period congestion significantly. Comparing the selected periods between 2018 and 2019, while 2019 had an increase of 12 per cent in average daily peak period VKT for the links directly impacted by the GUN, the normalised excessive delay cost and total costs were reduced by 67 per cent and 17 per cent, respectively. However, the completion of the GUN also led to a stagnation of public transport usage in the study area despite consistent population growth.

» **4. RPRL:** Following the opening of the RPRL in October 2016, an instant shift towards a higher public transport (rail) mode share can be observed. Comparing June to August 2016 (before-period) to June to August 2017 (after-period), the mode share at SL 3 increased from 0.1 per cent to 5.7 per cent (plus 5.6 per cent). This trend of above-average values for the RPRL also continued into 2018. The mode share shifts at the other SLs were lower (plus 1.4 per cent to plus 3.9 per cent) but increased as well, indicating uptake of public transport usage. It is concluded that the above-average figures for the RPRL are due to the particularly high population growth near the new RPRL (SL 3) and the availability of the new rail line with increased capacity and truncation/ rerouting of bus services.

As part of the project, the project team also developed a beta version of the Bruce Highway cost of congestion analysis Excel spreadsheet tool that enables fast processing of the before-and-after analyses.

This tool can be used directly to compute the high delay cost, reliability cost, average volumes, average speeds, vehicle delay, and other key performance indicators at the Bruce Highway study route's link level or route level.

Aerial View of Brisbane City in Australia at Sunset

Source: Shutterstock 2212848371

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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GET INVOLVED

The NACOE Program runs on a rolling five-year basis, with projects generally spanning one to three years. The program relies heavily on input and collaboration between TMR, NTRO, 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, www.nacoe.com.au or by sending an email to info@nacoe.com.au.

NACOE 10 YEARS ANNIVERSARY

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