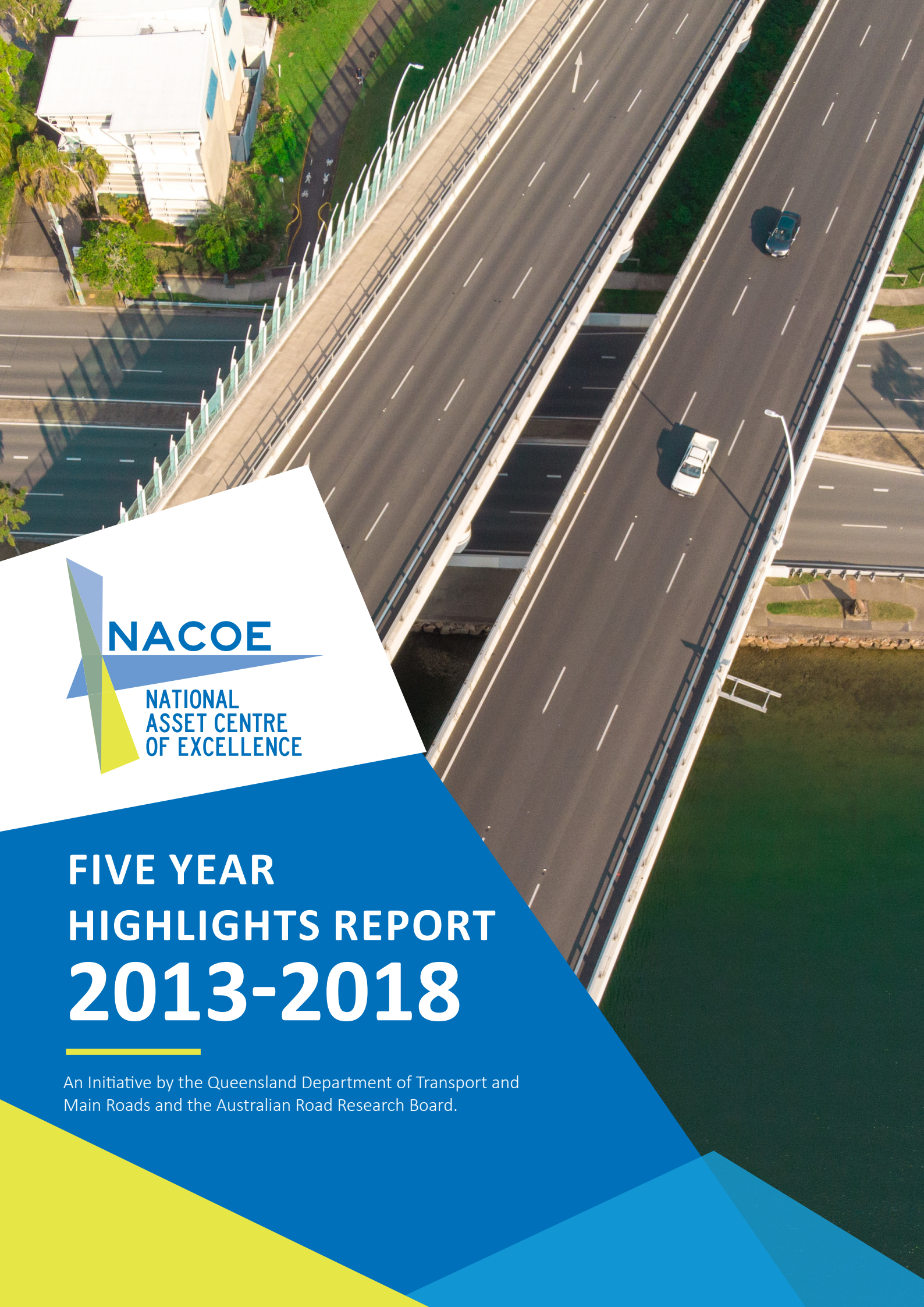


NACOE
NATIONAL ASSET CENTRE OF EXCELLENCE

FIVE YEAR HIGHLIGHTS REPORT 2013-2018

An Initiative by the Queensland Department of Transport and Main Roads and the Australian Road Research Board.

FOREWORD

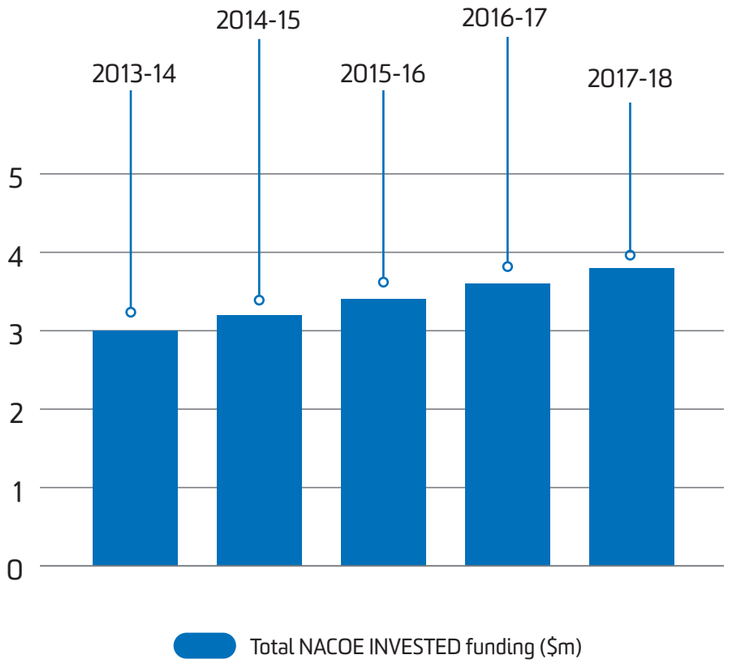
In December 2012, the Queensland Department of Transport and Main Roads (TMR) and the Australian Road Research Board (ARRB) signed a new partnership Agreement. The new Agreement has a broad scope and includes committed funding for capability development, research, and technology transfer. The primary technical focus of the Agreement was to create a National Asset Centre of Excellence in Queensland.

The National Asset Centre of Excellence (NACOE) commenced in July 2013, and June 2018 marked the completion of five years of collaborative research between the two organisations. Over this period, around $22.6 million of NACOE research has been carried out by TMR and ARRB, including funding by third parties.

Since 2015, an annual Highlights Report has been published to reflect on progress in the preceding financial year across the four sub-programs, as well as against the other NACOE program priorities including knowledge dissemination and capability development.

As 2017/18 marks a five-year milestone, this report provides an overview of some of the key achievements and projects over the life of NACOE.

It will demonstrate how the research has benefited Queensland and the wider transportation industry.



OUR MISSION

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

- Unlocking innovation
- Implementing international best practice
- Translating new knowledge into practice

STRATEGIC OBJECTIVES

DEVELOPMENT

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

COST SAVINGS

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

COLLABORATION

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

IMPLEMENTATION

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

ACKNOWLEDGMENTS

We would like to acknowledge our partners, the Queensland Department of Transport and Main Roads (TMR) and the Australian Road Research Board (ARRB) for their collaboration on the development of the NACOE Program over the past five years.
We would also like to thank and acknowledge the organisations, universities and industry associations who collaborated on NACOE projects, of whom without their valued support and input, much of the road research work we do, would not be possible.

ABOUT OUR PARTNERS:

Queensland Department of Transport and Main Roads (TMR)

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

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

Australian Road Research Board (ARRB)

ARRB was founded in 1960 and is the source of independent expert transport knowledge, advising key decision makers on our nation's most important challenges. ARRB has a strong heritage of supporting and delivering high quality applied research for Australian and New Zealand state road agency members and for the community.

SECONDMENT SUCCESS STORIES

The development of TMR and ARRB staff capabilities (through secondments) is a strategic objective of NACOE. Over the past five years, the TMR/ARRB Agreement laid out a process for secondments between the two organisations.

Since the Agreement was signed, there have been nine ARRB staff seconded to TMR, working on various road related projects such as expansive subgrade assessments, suitability assessment of hydrated lime vs quicklime, and internal improvement projects. A further four TMR personnel have been seconded to ARRB,working on projects such as benefits of traffic speed deflectometer (TSD) data in pavement analysis, implementation of thin asphalt surfacings, implementing the international climate change adaption framework, effectiveness and appropriateness of pavement drains, TMR Weight in Motion (WiM) Strategy, and manual of repairs for non-timber bridges. The time frames of these secondments were ranging from two months up to four years.

Below is a testament to the benefit of these secondments.
'When Angela Ransom from TMR joined the ARRB Structures team, she contributed to the development of a new repair manual for repairs of non-timber bridges and helped shaped the new TMR WIM strategy'.

Over the same period, ARRB Chief Technology Leader Tim Heldt joined the TMR Structures Management team. His role included introducing best asset management practices and frameworks to enable TMR's Structures team to transition into a more effective Strategic Asset Management role.

Through close collaboration, excellent team work and Tim's extensive asset management experience, the project successfully developed Levels of Service, Assessment Criteria and defined the critical bridge network as: Network, Region and Technically Critical Bridges.

Apart from extensive project benefits, the secondment process has enhanced the mutual relationship between operational team members to the benefit of both organisations.

WHO WE ARE

NACOE represents the strongest collaboration between TMR and ARRB to date, however it builds upon a long and productive working relationship dating back to the 1980s.
TMR has been working on many of the research topics discussed over decades and has a proud, longstanding history of developing innovative transport solutions, such as foamed bitumen stabilisation, using marginal and non-standard materials in regional areas and optimising the use of sealed granular pavements across their extensive road network. NACOE has created an opportunity to dwell more into these areas and provide enhancement for the benefit of users and the community.
The purpose of the partnership between TMR and ARRB is to unlock innovation and maximise knowledge transfer into practical, implementable research. Through this collaboration, both organisations can leverage off their combined research resources and remove barriers to innovation.

UNLOCKING INNOVATION, IMPLEMENTING INTERNATIONAL BEST PRACTICE AND TRANSLATING NEW KNOWLEDGE INTO PRACTICE

During the late 1990s and 2000s, TMR embarked on a research program in which ARRB was engaged to deliver research projects on an ad-hoc basis, with a more formal agreement reached in 2007. A Heads of Agreement between TMR and ARRB was signed in December 2012 which set out several initiatives that each would strive to achieve. Amongst those initiatives was the establishment of NACOE.

The NACOE research program covers four key discipline areas:

- Pavement technology
- Asset Management
- Structures
- Other, compromising;
- Sustainability
- Road Safety
- Network operations
- Heavy vehicle management

TMR and ARRB maintain a broad network of contacts and affiliates with interstate and overseas research efforts to share key learnings and identify promising developments, including Austroads and the Western Australia Road Research and Innovation Program (WARRIP).

An early focus of NACOE was the local adoption of proven innovative technologies from overseas. While this research was identified as having potential for 'quick wins', it was critical that these technologies were adapted to the unique climate, materials, geography, operational requirements, and test methods encountered in Queensland.

It was quickly recognised that in order to capture maximum benefits from this research investment, findings must be converted into tangible outcomes and filter down through TMR practice.
Methods adopted to achieve this include:

- publication and updates to specifications, technical notes, and design guides
- implementation through demonstration projects
- dissemination of learnings through presentations, workshops, seminars and webinars
- publishing technical reports and papers
- fostering secondments between the two organisations
- collaboration with industry bodies such as Austroads, the Australian Asphalt Pavement Association (AAPA) and the Australian Recycling and Stabilisation Association (AustStab), as well as universities, local government and other road agencies.

ACHIEVEMENT

Across the four sub-programs, NACOE is continuing to deliver strong economic and sustainability benefits to the department and the broader Queensland community. The program has delivered many high value research projects since it started in 2013, with the potential for economic savings being a key factor in project selection and delivery. Some of the key benefits of NACOE to-date include:

- a significant reduction in the required thickness of heavy-duty asphalt pavements, which 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
- environmental benefits through the increased use of recycled materials in road construction, most notably the use of crumb rubber from end-of-life car tyres in sprayed seals and
- reduced ongoing agency costs due to improved whole- of-life transport solutions, including building resilience in the face of extreme climatic events
- improved asset management modelling, tools and practices that have resulted in reduced agency and road user costs
- improved guidance to the department for reducing crash risks on Queensland roads.

An economic analysis undertaken in year three of the NACOE research program suggested that a number of key projects delivered have cost saving potential (depending on implementation). The same study estimated a benefit/cost ratio greater than 10, which is typically in the upper range of similar international research programs.

There has also been an increased focus on servicing the needs of regional Queensland, with a series of projects focused on lower-cost treatments and harnessing local materials and knowledge.
The benefits of NACOE are continually monitored to ensure that the department allocates its research funding in areas that will continue to make a positive economic, social, and environmental impact for all Queenslanders.

198
PROJECTS COMPLETED

608
MILESTONES DELIVERD

69
PUBLICATIONS DEVELOPED

MILESTONES

PAVEMENTS

The Pavements sub-program has been the largest component of the NACOE program with a focus on practical, implementable research to develop highly specialized technical capabilities in Queensland. Notable outcomes have been achieved in each of the following areas:

Research areas include;

- asphalt
- sprayed sealing and road surfacing
- stabilised/modified pavements
- unbound granular and marginal materials
- sustainability and recycling in pavements
- innovative pavement technologies and equipment.

Sprayed sealing and road surfacings

Asphalt

Sustainability and recycling in pavements

Stabilised and modified pavements

ASPHALT

Introducing EME2 to Queensland Reducing the thickness of full-depth asphalt pavements

Enrobé à Module Élevé (EME), otherwise known as 'high modulus asphalt', was developed in France in the late 1980s in response to the need to build stronger and longer lasting pavements. With further development, the use of EME was extended to airport pavements and major highways, and the second generation (EME2) is extensively used across France and elsewhere in Europe.

EME2 is a structural asphalt which offers increased stiffness, fatigue, and rut resistance properties over conventional unmodified asphalt base course mixes. To achieve these performance enhancements, a very hard grade of bitumen is used in the asphalt mixture at a high binder content, which along with some changes to the grading of the mix, leads to improved outcomes for Queensland through:

- a reduction in the asphalt base course thickness of up to 25% to achieve the same design life, resulting in reduced costs, reduced construction time and reduced use of scarce natural resources and GHG emissions
- alternatively, a substantial increase in the service life of the pavement if the equivalent layer thickness is used and
- a reduction in time required for pavement construction, reducing delays to road users, businesses and residents near works.

The early work toward the introduction of EME2 into Australia was undertaken by Austroads, TMR, ARRB and AAPA. In 2014, this culminated in the first EME2 trial project in Australia in Brisbane where 315 tonnes of EME2 was laid. This trial proved that locally procured aggregates and bitumen could produce EME2 asphalt consistent with French specifications, which had been adapted to Australian conditions and practices.

REDUCED COSTS, REDUCED CONSTRUCTION TIME AND REDUCED USE OF SCARCE NATURAL RESOURCES

To facilitate its broad scale introduction into Queensland, 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. NACOE also developed a new specification, MRTS32 High Modulus Asphalt (EME2), which was the first EME2 specification in Australia. To complement this research, another related initiative was the development and publication of TMR Technical Note 167 A New Approach to Asphalt Pavement Design which related to the procedures to test modulus and fatigue properties of asphalt mixes during pavement design.

Since the initial work under Austroads and NACOE, a series of further demonstration projects have taken place in Queensland and around Australia, and EME2 has now been utilised as a pavement base layer across several recent and ongoing major projects in south east Queensland.

STABILISED AND MODIFIED PAVEMENTS

Stabilisation practices in Queensland

The stabilisation of road construction materials has been extensive across Queensland, with a number of stabilisation technologies currently available (i.e. cement stabilisation, cement modification and foamed bitumen stabilisation), each with distinct benefits and limitations. In Queensland, the selection of a stabilisation treatment for a given application is heavily influenced by local practice and there was not a state-wide effort in place to characterise the relative performance of these various technologies over time. NACOE research has delivered significant savings by providing state-wide consistency in the selection of the appropriate stabilisation method and aligning design and construction practices to international best practice.

The early focus of this research was in plant-mix cement modified bases and in situ foam bitumen stabilised bases. With the majority of roads treated with these technologies currently in good to excellent condition, including several that have exceeded the original service life estimates.

Foam bitumen in particular has been utilised in flood-prone locations due to its ability to withstand prolonged inundation. Pavements treated shortly before Cyclone Debbie in early 2017 exceeded expectations and minimised reconstruction costs after this major event.

Stabilisation technologies provide long-term performance benefits at a significantly reduced cost to full-depth asphalt, and as such increased utilisation of these technologies can result in significant reductions in both construction and maintenance expenditure.

STABILISATION TECHNOLOGIES PROVIDE LONGTERM PERFORMANCE BENEFITS AT A SIGNIFICANTLY REDUCED COST TO FULL-DEPTH ASPHALT

NACOE

An economic analysis has shown that utilising a cement modified base can lead to savings of $50 to $130 per m2 when compared to a similar standard hot mix asphalt base layer, which translates 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 provide guidance to practitioners regarding best practice for the investigation, design, and construction of these technologies.
Using TMR as a benchmark, AustStab have moved to harmonise foam bitumen stabilisation practices and specifications across Australia.

Queensland trial of high-standard granular base

In 2013, a heavy-duty unbound granular pavement, using a high standard granular (HSG) base was constructed on the Centenary Motorway to demonstrate the suitability of this pavement type as a low-cost alternative to heavy-duty bound pavements. HSG pavements can have lower upfront costs, but potentially come with increased long-term maintenance and performance risks. TMR had trialled these pavements in the past with varied success, however this project showcased how they can be used successfully, and early performance assessment data suggests that the pavement is performing well after over five years of service .

PUTTING RESEARCH INTO PRACTICE

TMR SPECIFICATIONS AND TECHNICAL NOTES

NACOE has focused on producing tangible outcomes from the research being undertaken, and these granular materials projects are a prime example.

Following the success of the alliance between TMR and TrackStar to upgrade a stretch of motorway in Brisbane, NACOE assisted in developing a new pavement material specification, in which changes were implemented in MRTS05: Unbound Pavements to allow for the use of these HSG bases, and Technical Note 171: Use of High Standard Granular (HSG) Bases in Heavy Duty Unbound Granular Pavements was also published in August 2017.

Further changes to MRTS05 included incorporating a 'Modified C' grading in addition to the existing C grading, allowing this grading to be specified for TMR granular pavement works.

Case study on Modified C grading

TMR spends significant funds on the management and maintenance of its unbound granular pavement network, which comprises approximately 85% of the state-controlled road network. Many of these pavements are now carrying significantly higher traffic loadings than originally envisaged and much of this network has reached, or exceeded, its expected design life.

Some regions have been experiencing problems with 'boney' granular pavements specified to conform to the 'C' grading envelope in MRTS05 Unbound Pavements. This has led to the introduction of a 'Modified C' grading, which effectively removes the outer limits of the 'C' grading. The major change is an increase in very fine material, which is intended to reduce permeability, improve workability on site and lead to a better surface finish.

A SERIES OF SITE INSPECTIONS, CONSULTATION WITH SELECT REGIONS AND INDUSTRY, AND A COMPREHENSIVE LABORATORY TESTING PROGRAM

Under NACOE, a series of site inspections, consultation with select regions and industry, and a comprehensive laboratory testing program established that the 'Modified C' grading does reduce permeability and has only a minor effect on strength. Evidence suggests that moving to the 'Modified C' grading may lead to minor cost increases in some cases, but with the benefit of a less permeable grading improving the performance of unbound pavements across Queensland. Moving to a more resilient pavement layer will lead to significant reconstruction cost savings after major weather events, with the shift to a 'Modified C' grading appearing to reduce the likelihood of water infiltration.

Evaluating the performance of TNRP flood repair works

Between 2010 and 2013, Queensland experienced widespread flooding over most of its road network. Repairs to the resulting damage cost $6.4 billion and were constructed under the Transport Network Reconstruction Program (TNRP).

Given the scale of the area affected, the TNRP provided TMR with an excellent opportunity to identify optimal reconstruction practices to manage extreme weather events. This NACOE project identified best practices and lessons learnt from the TNRP, particularly in pavement design and repair techniques. The findings will be used for the improvement of design guidelines for future flood recovery works, as well as assist in selecting treatments and materials that are more resilient in the face of extreme weather.

AN EXCELLENT OPPORTUNITY TO IDENTIFY OPTIMAL RECONSTRUCTION PRACTICES TO MANAGE EXTREME WEATHER EVENTS

This project combined the most recent ARMIS condition data and information from ARRB's Intelligent Pavement Assessment Vehicle (iPAVe) surveys to assess the condition of the TNRP network. Field and laboratory testing have also been conducted at selected sites to gather additional data. The large pool of data provided a comprehensive tool for evaluation of the TNRP pavements.

CYCLONE DEBBIE 2017

DID WE PASS THE TEST?

Cyclone Debbie in early 2017 presented a great opportunity to assess the early resilience of pavements reconstructed after the 2010-13 weather events.

Debbie hit South East Queensland hard, particularly at many of the reconstructed range crossings that were previously wiped out. Notably, none of the reconstructed sections required major repair works after Debbie, and sections constructed with foam bitumen were especially well-performing.

Creating a circular economy using RAP

The incorporation of reclaimed asphalt pavement (RAP) materials into new asphalt mixes have many benefits including reduction of cost, reduction of greenhouse gas emissions, and conservation of natural resources such as bitumen, sand, and crushed rock. TMR has allowed up to 15% of RAP to be used in many asphalt mixes. However in more recent times, many newer asphalt plants have demonstrated an ability to incorporate more than 15% RAP in new mixes.

Before allowing increased percentages in TMR specifications, NACOE firstly investigated key measures required in testing, stockpiling, design, and manufacturing to maximise RAP percentages while minimising the risk of compromised performance.

NEWER ASPHALT PLANTS HAVE DEMONSTRATED AN ABILITY TO INCORPORATE MORE THAN 15% RAP IN NEW MIXES

This is a project where collaboration under Austroads and Western Australian Road Research and Innovation Program (WARRIP) has been key to unlocking benefits for all parties. It is envisaged that as technology improves further, RAP may become an even larger component of new asphalt mixes.

Recycled car tyre rubber in spray seals and asphalt

End-of-life vehicle tyres are a potentially valuable resource for recycling. However, at present, most tyres in Queensland end up in landfill, are dumped, or are exported overseas. Rubber and carbon black represent approximately 70% of the weight of a tyre, and one potential high-value application for these materials is as crumb rubber modified (CRM) bitumen for use in road construction.

The use of CRM binder in both asphalt and sprayed seals can lead to much improved field performance. CRM binder has been extensively used internationally but has been largely confined to use in seals and only in some parts of Australia. NACOE has fostered a joint funding arrangement with Tyre Stewardship Australia (TSA), the Queensland Department of Environment and Science (DES) and industry, with the goal of significantly increasing the use of CRM binders in asphalt and seals throughout Queensland.

The project completed a review of the various applications for CRM, performance benefits, and barriers to implementation. Demonstration projects were also for CRM binder sprayed seal, CRM binder in both open-graded and gap-graded thin asphalt surfacing

While this project is expected to produce widespread environmental benefits through the recycling of waste tyres, there is also a potential saving in binder costs and evidence of improved performance with CRM products. At an estimated saving of six to ten percent in binder costs alone, the department could be expected to save one to two million dollars per year in sprayed sealing works across the regions. In fact, resealing programs are already heavily focused on utilising rubberised seals across regional Queensland.

Utilising CRM binder in open-graded and gap-graded asphalt mixes are expected to deliver further benefits, expected to include improved durability, UV resistance, reduced noise and water spray, and overall sustainability and environmental outcomes.

INDUSTRY AWARD FOR CRM INNOVATION

The benefits of CRM have been highlighted with SAMI Bitumen being awarded an AAPA Innovation Award in 2017 for their work in hauling 2 million litres of CRM binder up to 1100 km to south west Queensland, a project that was awarded after being submitted as an alternative tender.

The ability to overcome technical barriers and subsequently harness performance benefits has led to further increases in utilisation of CRM binder.

INNOVATIVE PAVEMENT TECHNOLOGIES

Using geosynthetics to improve pavement performance

Road pavements in Queensland are vulnerable to movement and strength loss in natural soil subgrades, so it is a priority to identify cost-effective treatments to minimise damage to pavement assets. One such treatment is the use of geosynthetics. In partnership with the Queensland University of Technology (QUT), a project has investigated the performance of geosynthetics for mechanical stabilisation of weak subgrades, but also to investigate the potential for geosynthetics to reduce the thickness of granular base layers without compromising performance.

To do this, NACOE and QUT developed an innovative large-scale testing device to monitor and assess the performance under controlled conditions, and more accurately reflect field conditions.

IDENTIFY COST-EFFECTIVE TREATMENTS TO MINIMISE DAMAGE TO PAVEMENT ASSETS

ASSET MANAGEMENT

The Asset Management subprogram is focused on advancing asset management modelling practice and the underlying assumptions within these models. In addition, the program includes research into new funding strategies that explore life-cycle costing implications, particularly considering the risk of major weather events and flooding across Queensland.

Over the first five years of NACOE, the program has delivered benefit in terms of:

- more robust, reliable, and up-to-date asset management tools and models, which will enable TMR to better prioritise maintenance and rehabilitation spending, through informed decision making
- life-cycle costing of asset management strategies, with a focus on how to cost-effectively improve resilience of the network to rain and flood events with increasing climatic threats, and
- assisting TMR with the implementation and optimisation of private-sector road asset management contracts.

Improved modelling of pavement surfacing performance

Bituminous sprayed seals are the predominant surfacing type across TMR's regional network, however there is significant variability in performance and maintenance requirements. Premature seal failures not only require resealing but can expose the underlying pavement to moisture damage and rapid deterioration.

This NACOE project focused on methods for better understanding seal performance, including investigating non-destructive field tests. While no suitable test was identified at the time, a combination of improved modelling, more sophisticated use of network survey data, and the use of the Dynamic Shear Rheometer (DSR), will provide TMR with appropriate tools to instigate timely maintenance interventions and reduce the risk of premature seal failures.
TMR was also posed with a question of quantifying the effect of delayed or scaled-back maintenance practices on parts of its network. While it is understood that there will be a negative effect on pavement surface performance, existing models did not have the required data or performance history to be able to determine the extent of deterioration under different strategies. Further study under NACOE has allowed for a more comprehensive assessment in areas of the network with reduced maintenance, and changes have been implemented in TMR and Austroads performance modelling.

The linkages between ARRB, Austroads and other state road agencies has facilitated improvements to practice without requiring significant new fundamental research.

THE LINKAGES BETWEEN ARRB, AUSTROADS AND OTHER STATE ROAD AGENCIES HAS FACILITATED IMPROVEMENTS TO PRACTICE

Incorporation of the pavement risk score into the pavement condition index

TMR had developed a Pavement Risk Score (PRS) to reflect the risk to pavement preservation/failure and safety, which relies on measured condition data and information on the operating environment. A Pavement Management System (PMS) was also introduced together with the Pavement Condition Index (PCI).

This NACOE project reviewed, calibrated, and incorporated the PRS into the PCI and PMS. The formulation and optimisation of these factors are critical for resource requirements and utilisation, as well as the setting of realistic performance targets.

Experience shows that early automation and streamlining of calculations brings substantial benefits in terms of efficiency and reliability of the asset planning/modelling work.
This improved understanding will allow for consistent assessment of the risks to TMR and road users from current and future budgetary allocations.

Several reviewed elements were implemented in the department dTIMS model in January 2016. This implementation will reduce the quantity and complexity of the code and reduce run time of assessments.

AWARD-WINNING OPTIMISATION OF OUR PAVEMENT MANAGEMENT SYSTEMS

The NACOE project team, consisting of Dr Peter Kadar, Dr Tim Martin, and Ranita Sen of ARRB, and Michelle Baran of TMR, co-authored a paper exploring some of the key outcomes of this NACOE research. The paper, titled *Addressing Uncertainties of Performance Modelling with Stochastic Information* Packages, won the Innovation Award at the 9th International Conference on Managing Pavement Assets in Virginia, USA.

Accounting for life-cycle costing implications and network performance risks of rain and flood events

Between 2010 and 2013, the Queensland road network was impacted by a series of major cyclone and rainfall events that caused $6.5 billion dollars of damage to the network. The Transport Network Reconstruction Program (TNRP) was established to facilitate the state-wide recovery of the state-controlled road network. This project sought to quantify the impact of these events in a life-cycle costing framework, and to identify the funding levels required to improve the resilience of the network as it responds to future events.

A series of case studies were developed that enabled a comparison of three investment scenarios; the base case of what actually happened, a full resilience scenario and a 'stitch-in-time' approach to road rehabilitation. A life-cycle costing model was developed to

SOUGHT TO QUANTIFY THE IMPACT OF THESE EVENTS IN A LIFE-CYCLE COSTING FRAMEWORK

facilitate this analysis. The study found that large benefits can be realised through the full-resilience option, but that this requires a very high agency investment. In contrast, the stitch-in-time approach may not require increased total agency costs, and still deliver reduced road user costs, and reduced flood damage risk. While the cumulative economic effect of the full-resilience model was negligible over 30 years across the case studies, for the stitch-in-time model the analysis calculated a cumulative lifecycle cost saving of nearly $600 million for a marginal benefit-cost ratio of 6.9.

A best-for-network strategy was also proposed, where the best option is chosen for each link, leading to an overall marginal benefit-cost ratio of 3.7. The anticipated life-cycle benefit of the best-for-network strategy could extend to $16 billion over the 30-year analysis period.

In addition, it was found that enhanced drainage maintenance across the state-controlled network will reduce the extent of damage. Based on this finding, $100 million of programmed maintenance, rehabilitation and drainage maintenance was accelerated in 2016-17.

STRUCTURES

The Structures subprogram seeks to deliver benefits to the network in several ways, including:

- destructive testing and analysis of vehicle interactions on load limited and critical bridges to gain a better understanding of the capacity and performance of these structures
- development of staff capacity in the use of advanced assessment technologies and instrumentation of structures
- improving bridge monitoring and management using advanced systems and by adopting world's best practice in asset and risk management
- introduction of advanced materials and technologies into structures across the network.

Measurement of bridge-vehicle interaction under live load

The need to extract more value from existing TMR investments including over 3,000 bridges and 4,000 major culverts, with a gross replacement asset value in excess of $11 billion is ongoing. Structural assessments conducted on these bridges consider the dynamic amplification of load due to heavy vehicles by applying various codified factors from AS 5100. TMR has invested heavily in load restricted bridges but would like greater clarity on dynamic loading of these structures. Of particular interest was the use of the Dynamic Load Allowance (DLA) factor, a parameter specified in the Australian Bridge Design Code. This NACOE project investigated whether this factor could be adjusted based on the actual structure, vehicle loadings, road profile and bridge condition.

Additionally, the validation of the hypothesis that substructures attract fewer dynamic impacts from vehicles than superstructure was of interest. The objective was to avoid unnecessary maintenance and access restrictions, and an increase in freight movements, translating to economic and efficiency benefits.

The investigation process included load testing of three representative bridges of different substructure types. Various test vehicles were employed (semi-trailers, road trains, 4-axle crane) and the response of the bridge to each of these vehicles at various speeds and direction of travel was recorded and analysed. The investigation specifically focused on interactions between vehicles and bridges, and the degree of variance that occurs with different parameters such as structure type, road profile conditions, vehicle and suspension type.

Project outcomes include that the vehicle and suspension type influence the overall dynamic response of the bridge, as does the condition of the road approaches to the bridge. Interpretation of individual bridge and vehicle responses in the frequency domain has also proven to be critical in understanding their dynamic interactions.

Deck unit bridge deck analysis under live load

There are over 1,900 transversely stressed deck unit bridges on the TMR network. This family of bridges is unique in its design and performance with a low level of transverse post-tensioning, upright external units and no shear keys. While standard assessments indicate that theoretical capacities are exceeded, the observed actual in-service performance does not necessarily indicate distress. Accurate modelling of this family of bridges has been difficult to achieve historically.

This four-year project NACOE undertook an extensive investigation program into the performance of deck unit (DU) bridges. The following outcomes of this program are key to implementing more accurate and defensible modelling and assessment methodology for these types of structures:

- The in-service bridge performs better than theoretical prediction (particularly lateral distribution), with its behaviour similar to a monolithic concrete slab.
- Individual units performed close to theoretical estimates in bending but significantly better in shear.
- Ultimate failure of the bridge was essentially ductile, with a minimal load redistribution between the edge unit and the internal units at failure. Ultimate failure of the bridge was not catastrophic due to the remaining load capacity in adjacent units.
- The loss of the transverse prestress in the transverse stressing bars (TSB) and damage of the mortar joints could result in a reduced level of structural integrity and onset of propagation of failure of the lateral load transfer mechanism.
- The integrity of the mortar joints plays a critical role in the transverse load transfer mechanism of the bridge superstructure, while the TSB contribute to the integrity of the mortar joints under loads maintenance expenditure. Improvements in our understanding of the capacity and remaining life of these critical assets is a major priority for TMR, and NACOE has been a key driver in the industry.

- Better understanding of the behaviour of deck unit bridges (40% of TMR bridge stock) in various scenarios including in-service, under high loads and with deficiency of structural components
- Provision of basis for TMR to review and calibrate the assessment methodology of existing structures using field measurements
- Improved confidence in the performance of deck unit bridges.

Long-term performance of FRP replacement structures and components

A limited number of existing complete fibre reinforced polymer (FRP) structures and structures with replacement FRP components have been identified on the TMR network. One of the objectives of installing these components is to gain practical understanding of the performance of the FRP material in bridge applications. Consistent with this objective, this project involved a performance review of FRP components and structures in the TMR network through visual inspection. In addition, TMR is interested in assessing the condition of its stockpiled FRP girders (manufactured by Wagner's Composite Fibre Technologies (WCFT) and Loc Composites and stored at several Districts) to determine whether it is appropriate to utilise them by visual inspection and serviceability load testing.
The project outcomes provided baseline knowledge for the performance of existing FRP components and structures under TMR management. The interaction between replacement FRP components and existing timber components are satisfactory, with no significant issues.

It was recommended that TMR retain investment in FRP and continues to improve its understanding of the material without significant further investment. This would position TMR to be the best-informed Australian road agency with respect to FRP, given its current advantage resulting from previous investments.

- Established the current status (defect mapping) of the existing FRP structures and components on TMR network and recommend maintenance and monitoring actions for these components
- Provided basis for the development of a continuing monitor/assessment program to further obtain long-term performance data of the FRP components and recommendations on the utilisation of stockpiled FRP girders
- Provided recommended options for TMR to consider for its FRP strategy.

BRINGING BRIDGE ENGINEERING EXPERTISE TOGETHER

NACOE has provided an opportunity to harness the combined bridge and structural engineering expertise of TMR, ARRB and Universities to undertake complex assessments and trials. The knowledge gained has not only provided TMR with a better understanding of the health of their bridge assets, it has promoted NACOE nationally as a hub for bridge research and investigation.

ROAD SAFETY

TMR and ARRB have collaborated on road safety research since before the establishment of NACOE, however the structured research program allowed for a series of multi-year research projects that harness ARRB's road safety expertise. Some key project outcomes have included:

- recognising dangerous links in the network and targeting these locations with road safety treatments, such as the use of wide centrelines on the Bruce Highway
- cutting the road toll by targeting key crash types and investigating cost-effective techniques to minimise serious and fatal injuries
- investigating and quantifying the effectiveness and safety outcomes for line-marking technology.

Wide centrelines proving their effectiveness on the Bruce Highway

As the primary north-south route in Queensland, the Bruce Highway performs a critical freight and movement task, but 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 61% of deaths on the Queensland network.

The Bruce Highway Action Plan is a state Government initiative to improve the operation and safety performance for 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, with wide centrelines expected to reduce overall FSI crashes by approximately 22% and reduce cross centreline FSI crashes (including head-on crashes) by approximately 43%. The value of this road safety improvement may be as high as $150 million per year if extended along the full length of the highway.

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

Investigating key crash types across Queensland

ARRB has led the way nationally through Austroads research in safety treatment effectiveness and crash data analysis. Drawing on this experience, a series of NACOE projects were established to review, analyse and develop solutions for prominent and especially high-risk crash types. This includes statistical analysis of crash data, as well as the use of rating tools such as AusRAP.
Australian and international research has established the effectiveness of various treatments over many years, and as such a series of recommended treatments have been proposed for Queensland based on the crash type. Among these recommendations were:

- Head-on crashes, which often have very severe outcomes for road users, can be combated through using wire-rope barriers (50% reduction in fatal crashes) or wide centrelines (75% reduction in crashes for the Bruce Highway)
- Treatments for run-off-road crashes include advanced curve warning signs, better curve delineation and shoulder rumble strips – with rumble strips estimated to deliver a 40% reduction in these crashes
- Crashes at intersections, accounting for nearly half of all injury crashes, can be minimised through adopting intersection types that have fewer crashes, or where outcomes are less.

CONSIDERATION OF ADVANCEMENTS IN TELEMATICS, ACCREDITATION, SOFTWARE MODELS AND TECHNOLOGIES

Evaluation of road-friendly suspension compliance using on-board vehicle technologies

Heavy vehicles fitted with road-friendly suspensions (RFS) are permitted to operate on select routes at higher mass limits. This productivity benefit is permitted on the assumption that an RFS reduces pavement damage. Despite evidence that the performance of a suspension does degrade over time, there is no quantitative test method to determine in-service compliance requirement for RFS.
The review included consideration of advancements in telematics, accreditation, software models and technologies and suggested possibilities of new ways for in-service testing of RFS.
The preliminary findings indicate that in the past the major obstacles to an in-service test for RFS have been:

- identifying a cost-effective approach that does not involve removal of components or major interruption to vehicle operation
- knowledge gaps and disagreement on the link between performance characteristics of a suspension, road friendliness and the amount of pavement wear.

An evaluation was undertaken by performing a field testing of selected RFS measurement technologies. The results of the tests have been summarised including limitations that would need to be considered prior to an operational evaluation in the final stage of the project.

Several in-service testing methods have proven suitable to explore further, however the lack of a suitable excitation method is a limitation that prevents an on-board technology being used to its full potential as an in-service test method.

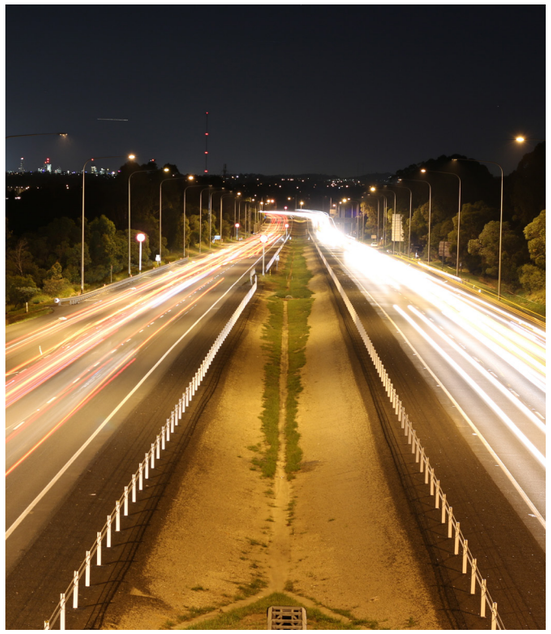
SELECTED AS THE WINNER OF THE DISTINGUISHED SCIENTIFIC PAPERS - ASIA PACIFIC AWARD

It has long been recognised that congestion causes significant economic costs on a city, but there has not been an effort to estimate these costs across travel modes. This project developed a methodology for estimating congestion costs for buses and freight, which undertook feasibility studies based on these modes as well as for bicycles and pedestrians.

In the first case study, Translink GoCard data was used to estimate bus commuter congestion, where it was found that congestion on an average weekday on Gympie Road was approximately $45,000. It was noted that passenger waiting times are a significant proportion of the total congestion delay cost of buses.

The second case study involved a before and after evaluation of a major urban road project (Bruce Highway ramp metering) to determine their congestion reduction impacts. The case study revealed that although the average daily vehicle kilometres travelled increased by 5%, the cost of congestion was reduced after the installation of ramp metering, from $100,000 per day in 2015 down to $80,000 per day in 2016.

This unique research was presented at the World Congress on Intelligent Transport Systems in Melbourne in October 2016, where it was selected as the winner of the Distinguished Scientific Papers - Asia Pacific award. The findings were also presented and discussed at a special workshop at the ARRB Conference in November 2016.



GET INVOLVED

HOW TO GET INVOLVED

The NACOE program runs on a rolling four-year basis, with projects generally spanning one to three years.
The program relies on the input and collaboration of the Queensland Department of Transport, ARRB, and Main Roads and industry personnel to develop ideas for projects across the four key discipline areas of pavements, asset management, structures and other (network operations, road safety and heavy vehicle management).
Any suggestions for projects can be submitted through the NACOE website, at NACOE.com.au or through the NACOE email address info@NACOE.com.au

FEEDBACK AND CONTACT DETAILS

The NACOE Agreement Managers can be contacted with any feedback or to make enquiries regarding the program or specific projects.

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An Initiative by the Queensland Department of Transport and Main Roads and the Australian Road Research Board.

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