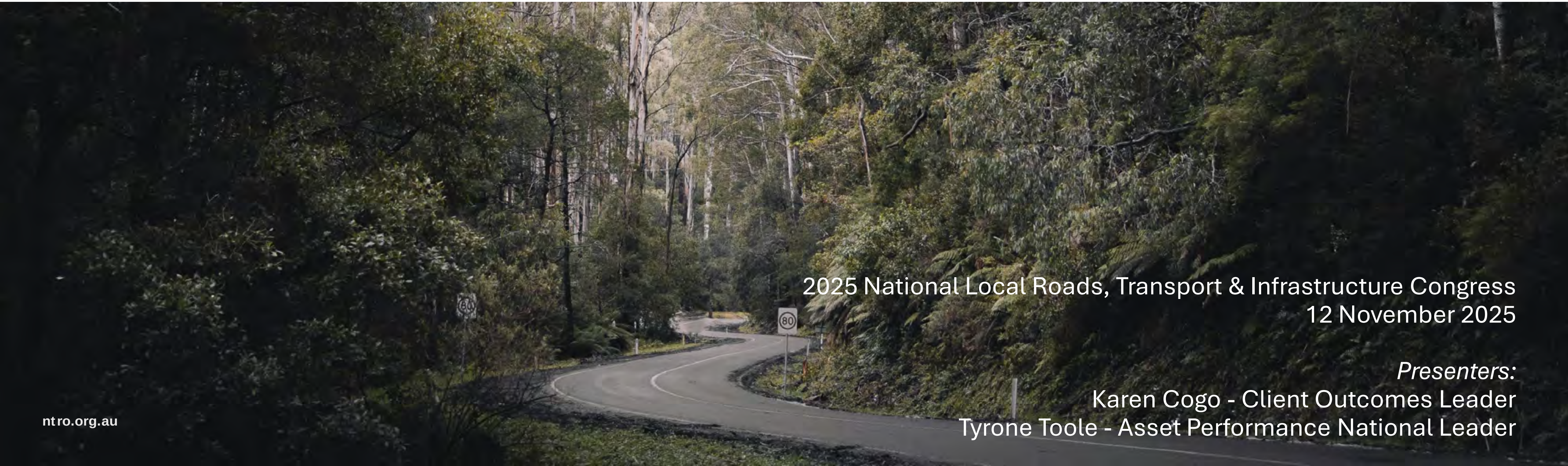
“Sustainable road construction practices incorporating **circular economy** principles and building **resilience** into road infrastructure networks.”

Session 6: Circular Economy and Resilience in Road Construction



2025 National Local Roads, Transport & Infrastructure Congress
12 November 2025

Presenters:

Karen Cogo - Client Outcomes Leader
Tyrone Toole - Asset Performance National Leader

It's not easy managing council infrastructure

Councils need affordable, sustainable, resilient and evidence-based solutions that deliver real outcomes.

1. Tight budgets, increasing community expectations
2. Ageing assets and growing maintenance backlog
3. Climate change impacts and disaster recovery pressures
4. Difficulty turning data into actionable decisions



The evolving challenge

① Infrastructure Vulnerabilities

- More frequent and intense extreme weather events
- Damage and disruption to transport infrastructure
- Increased road user and agency costs
- Greater maintenance and renewal pressures

The evolving challenge

1 Community and Economic Impact

- Disruptions affect access, emergency response, and economic activity in communities.
- Quantify risk and the resulting impacts, and measures to help communities recover and, most importantly, avoid or mitigate risks where this is feasible.

2 Measurement Challenges

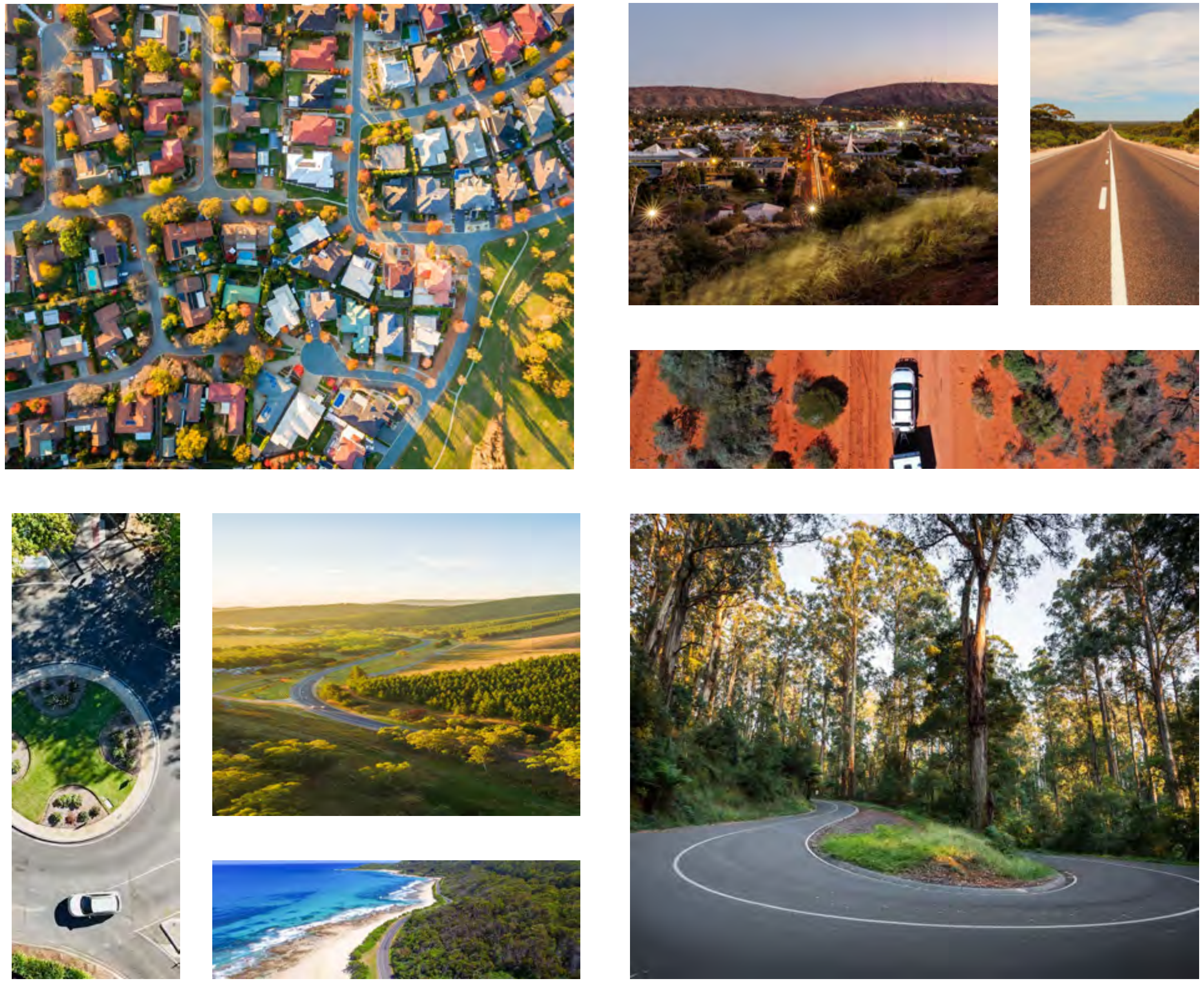
- Current frameworks lack tools to measure resilience investment effectiveness clearly.
- Proactive, preventive or mitigation actions or metrics will allow a strategic response which recognises future scenarios and plans and responds accordingly.

What's been the biggest climate challenge for your Council in the past five years?

- Flooding
- Heat
- Bushfires
- Coastal impacts
- Coastal Erosion
- Or something else?

Every Council is unique

- Different climates, geographies and risk profiles
- Varying access to materials, contractors and budgets
- Distinct community expectations and policy drivers
- No one-size-fits-all approach to resilience or sustainability



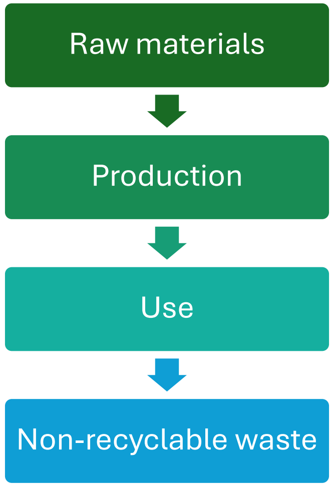
1. Understanding of circular economy applications in road construction

What is the Circular Economy in Roads?

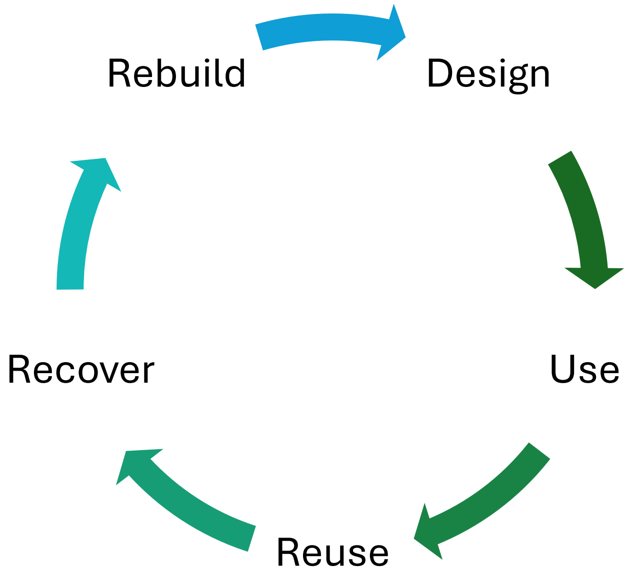
From Linear to Circular

- **Reuse** of recycled materials (glass, rubber, asphalt)
- **Minimise waste**
- **Extend life of assets**
- **Repurposing / optimizing onsite materials**

Linear Economy



Circular Economy



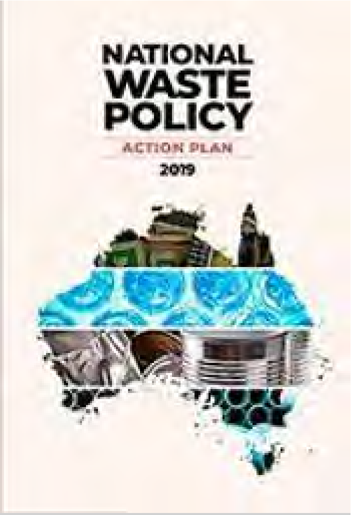
The four principles of responsible use of recycled materials

1. Engineering performance
   - Must be equivalent to conventional materials if not better

2. Short-term HSE requirements
   - Not be harmful or be a WHS risk to workers or the public

3. Long-term environmental impact
   - Not generate harmful leachates or unwanted microplastics

4. Be fully recyclable
   - Must be recyclable at end-of-life to support the circular economy



Towards Circular Economy and Resilient Roads

Feasibility assessment

Identify focus materials, untapped waste streams or emerging industry opportunities.

Application selection

Understand potential applications within the transport corridor.

Health, safety and environmental

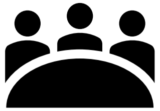
Consider health, safety and environmental risks, and whole of life impacts.

Product development

Engage with industry innovators to support product development and provide independent testing and certification.

Standards and guidelines

Develop standards, specifications, guidelines and technical documentation.



Stakeholder consultation

Laboratory study

Field demonstration/validation

Performance monitoring

What this means for Councils

Pragmatic adaptation towards a Circular Economy & Resilience in Infrastructure

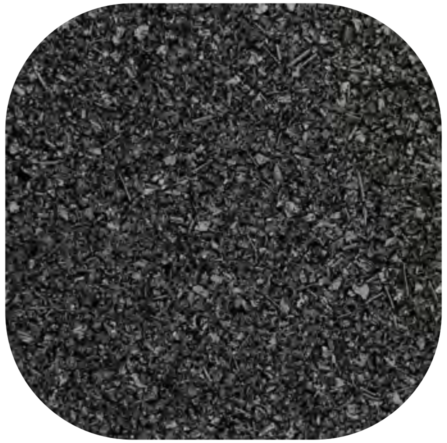
- Need to move from reactive maintenance to proactive/resilience planning
- Implications to budgets, asset management plans, risk registers
- Strategies to build infrastructure resilience
- Sustainable road construction using circular economy principles
- Practical tools and case studies for infrastructure owners
- Importance of data for monitoring trends (including extreme event induced step changes) and responding to changes in condition

Recycled Materials in Road Infrastructure

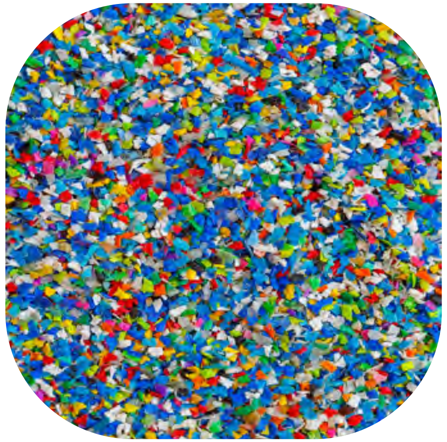
- Crushed Concrete and Brick
- Recycled Crushed Glass
- Reclaimed Asphalt
- Crumb Rubber
- Ground Granulated Blast Furnace Slag
- Fly Ash
- Bottom Ash
- Recycled Organics
- Recycled Plastics

RECYCLED CRUSHED GLASS

CRUMB RUBBER



PLASTICS



Recycled material uses, potential and savings

Material	Example uses	Replacement / substitution potential (%)	Available Standards / Guidance	Cost saving (%)	GHG impact (%CO2e)
1. a) Crushed Concrete b) Brick	Granular subbase	[redacted]	[redacted]	[redacted]	[redacted]
2. Recycled Crushed Glass	Asphalt, unbound granular, drainage	[redacted]	[redacted]	[redacted]	[redacted]
3. Reclaimed Asphalt	Asphalt WC & BC	[redacted]	[redacted]	[redacted]	[redacted]
4. Crumb Rubber	Sprayed seals and Asphalt	[redacted]	[redacted]	[redacted]	[redacted]
5. Ground Granulated Blast Furnace Slag	Subgrade, Cement replacement	[redacted]	[redacted]	[redacted]	[redacted]
6. Fly Ash	Pavement stabiliser	[redacted]	[redacted]	[redacted]	[redacted]
7. Bottom Ash	Granular subbase	[redacted]	[redacted]	[redacted]	[redacted]
8. Recycled Organics	Mulch	[redacted]	[redacted]	[redacted]	[redacted]
9. Recycled Plastics	Asphalt, walls, sleepers, pipes	[redacted]	[redacted]	[redacted]	[redacted]

Source: Best Practice Expert Advice on the Use of Recycled Materials in Road and Rail Infrastructure, Part B, Table 1.1 (Use/content), Table 2.2 (GHG), Table 2.6 (Cost)

Case Study: Recycled crushed glass

Recycled crushed glass (RCG) recovered from waste glass

Crushed to nominal size 4.75mm, free of contaminants, washed or unwashed

- Pavement subbase, base and wearing course
- Sand replacement in general concrete paving
- Bedding and granular filter materials
- Coloured and high friction surface treatments

NTRO involvement in various RCG projects includes product/mix design and testing, local government field trials, EPD development, development of standards and guidelines.

Case Study: Increasing use of RCG

(Austroads APT6311)

Use of recycled crushed glass in various applications:

Bedding and backfill

Drainage applications

Embankment fill

Landscaping

Concrete for paving and non-structural applications

The project resulted in:

- Austroads Technical Specification for the production of a recycled crushed glass sand.
- Technical basis report and guidelines around the processing of glass

The project was funded by the ITSOC (Infrastructure and Transport Senior Officials Committee). Part of the Austroads Transport Infrastructure program

Case Study: Construction of field trials using blend of recycled crushed concrete and glass

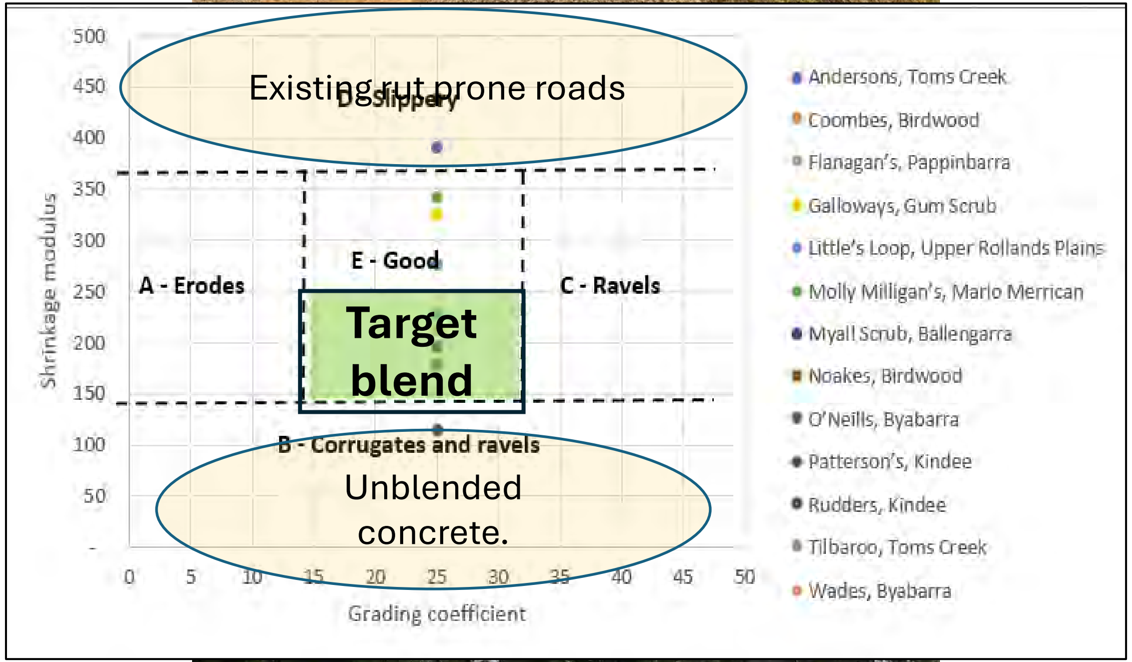
Marion Street in City of Canterbury Bankstown on Sydney, NSW

Case Study: Recycled materials in improving unsealed roads

(NTRO Port Macquarie and Hastings study and Austroads AAM6143)

- Problem(s):
  - Wide variation in unsealed materials and performance. Is maintenance strategy correct and how should backlog in resheeting be tackled?
  - Can recovered concrete building materials be used, and what practice improvements are needed for improving unsealed roads ?
- Solutions:
  - Utilise crushed concrete materials on rut prone roads with thin residual gravel to improve performance and extend lives
  - Continue practice of heavy grading and surface reshaping to maximise lives of unsealed roads.
- Benefits:
  - Improved road wear rates, less rutting and material loss, and reduced slipperiness.
  - Reduces need for new compliant unsealed materials by blending

NTRO involvement included review of unsealed practices, validation of grading techniques and frequencies and recommendations on extending life of existing assets through best use of available in situ and imported materials.



Summary of material uses, potential and savings

Material	Example uses	Replacement / substitution potential (%)	Available Standards / Guidance	Cost saving (%)	GHG impact (%CO2e)
1. a) Crushed Concrete b) Brick	Granular subbase	100% 20%	Vic, Qld Vic	-44% -14%	-52%
2. Recycled Crushed Glass	Asphalt, unbound granular, drainage	5-10%, 10-50%, 100%	Vic, Qld, NSW, IPWEA, WALGA	-2%	+127% from transport
3. Reclaimed Asphalt	Asphalt WC & BC	20%, 40%	NSW	-83%	-98%
4. Crumb Rubber	Sprayed seals and Asphalt	20% (by mass of binder)	Austroads, NSW	-46%	-47%
5. Ground Granulated Blast Furnace Slag	Subgrade, Cement replacement	5%, 20-40%	Qld, NSW	-27%	-73%
6. Fly Ash	Pavement stabiliser	50-70% (binder)	Austroads, NSW	-40%	-98%
7. Bottom Ash	Granular subbase	10%	NSW	-100%	+44%
8. Recycled Organics S	Mulch	100%	ARRB	-71%	-
9. Recycled Plastics	Asphalt, walls, sleepers,, pipes	5% (binder), 75%, 100%, 100%	ARRB, NACOE, WARRIP	-64%, 78%, -52%, -52%	-65%. -, -90%, -90%

Source: Best Practice Expert Advice on the Use of Recycled Materials in Road and Rail Infrastructure, Part B, Table 1.1 (Use/content), Table 2.2 (GHG), Table 2.6 (Cost)

Benefits and Challenges for Councils – Circular Economy

1 Benefits

- Lower material cost, sometimes better local sourcing, enhanced sustainability credentials

2 Challenges

- Procurement policies, contractor capability, performance assurance, standardisation, perception risk

Quick checklist for Councils

- Does our asset-management plan **reflect** material resilient and reuse opportunities?
- Are we **engaging** procurement and contractors about circular-economy and resilient options?
- How do we **monitor** performance of recycled or reused materials over time?
- Are there regulatory or specification **barriers** (risk management, warranties)?
- Set an action: Review **one** road-project this year with a circular-economy lens.

2. Resilience-Building Strategies for Road Infrastructure

Resilience – what is it?

- The ability to survive in the face of complex, uncertain and changing circumstances, and is a way of thinking about both long-term cycles and long-term trends.
- Ability to reduce the magnitude and/or duration of disruptive events and deliver your target LOS.
- The ability to anticipate, absorb, adapt to, and/or rapidly recover from a potentially disruptive event.

Infrastructure and resilience – an Agency's view

The purpose of infrastructure is to provide services to customers - i.e. move people and goods efficiently

The value of infrastructure is about the services it delivers to customers

Resilience is about the ability to 'spring back' or recover from difficulties

If a road is not open because it cannot 'spring back' it provides no value to the customer

Planning for resilience

You already do!

- Road hierarchies, design lives and durability designs, and intervention strategies are examples of planned resilience.
- The challenge is recognising the parameters that will change, though the scale and areal extent are not reliably known.
- Historical observations alone are insufficient for future planning; however, they have value especially in demonstrating impacts and effectiveness of practices.
- Resilience planning must address the need for chronic, systemic changes in managing the 'normal' as well as the changing conditions, and shock events

Unfortunately, we neglect the obvious and lessons from the past, both historical and recent, with readiness being very low – certainly for roads – the focus of this presentation.

A focus on roads: increased treatment and budget demand from significant climate events

Sealed arterial roads in Queensland (2010 – 2013)

- $7 Billion for State roads only, 8,000 lane kms of rehabilitation (11% of network cway kms) – state-wide impacts and disruption.

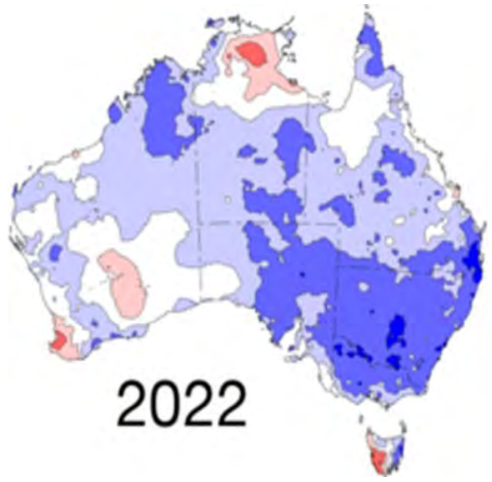
Sealed arterial roads in Victoria (2022)

- Additional 380km (1.7% of network km) of rehabilitation need added to accumulated backlog, and 460 km of resurfacing (2% of network cway kms) – regional impacts and disruption.

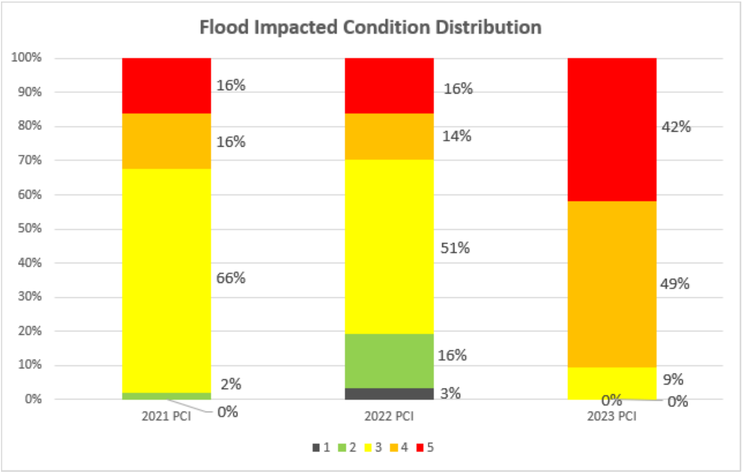
Unsealed LG roads on a single impacted mine haul route in WA (2021)

- Cost of access restoration 5 - 30 times annual surface preservation expenditure – loss of access.

Were we surprised?



Were we ready?



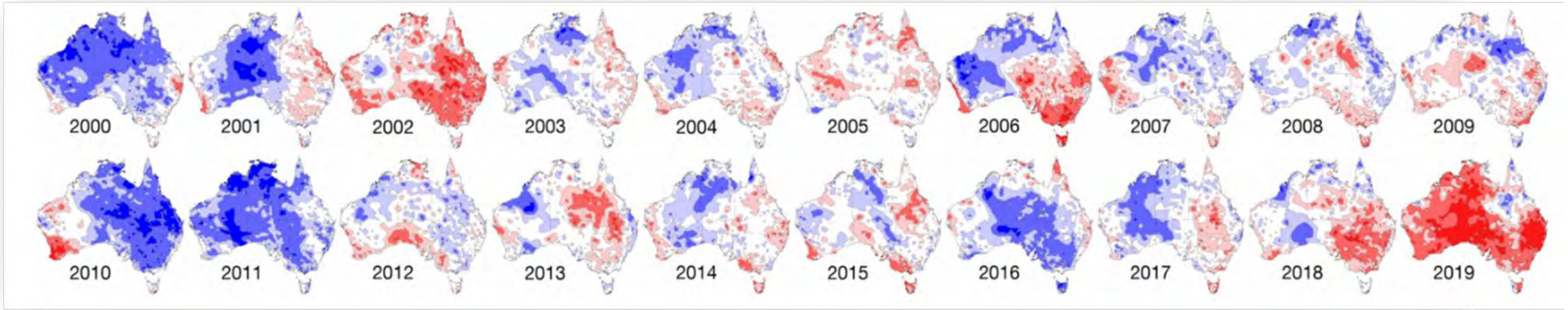
3. Changing conditions for road infrastructure: What are they and how can we inform action?

Changing conditions and some underlying factors, lessons and solutions

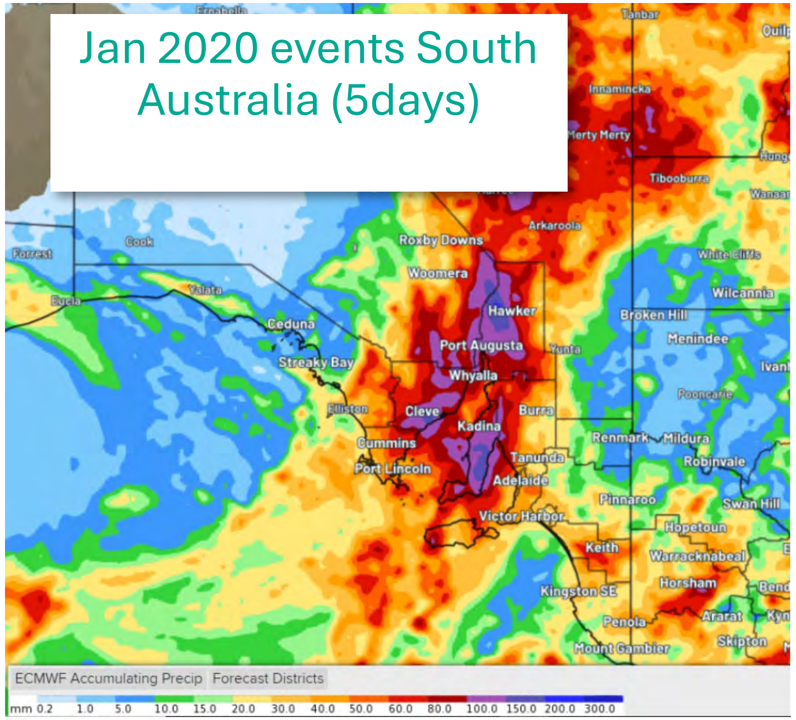
- Increased uncertainty in climate factors, but much of the damage was pavement deficiency related
- Where can the next significant impact be expected?
- What knowledge and experience can we draw on - How does pavement strength and performance change with moisture risk for sealed low volume roads?
- Long-term trends /cycles – lessons from history? Not a silver bullet but evidence-based guidance (e.g. Western Queensland Best Practice) may still be relevant.
- Predicting performance and treatment needs, retaining memory and adding solutions – remembering Granny's adage, and using and adapting evidence.

Increased uncertainty in climate factors

Queensland 2010 – 2013 events - much of the damage was pavement deficiency related

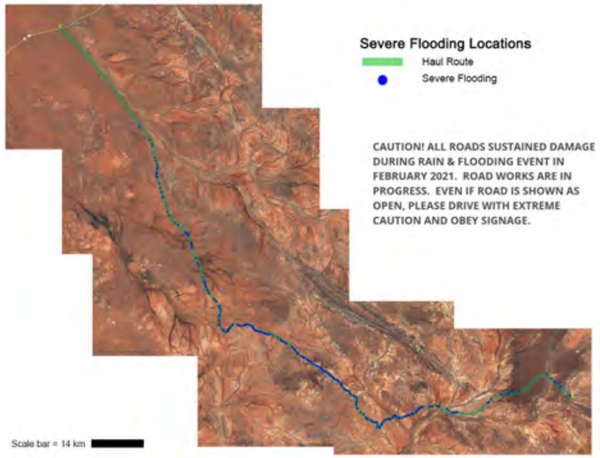


Where can the next significant impact be expected?

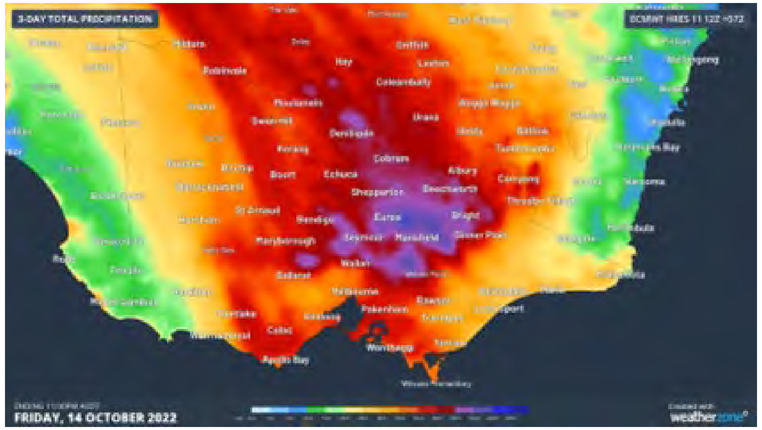


Jan 2020 events South Australia (5days)

Feb 2021 flooding impacts on unsealed roads in the Gascoyne

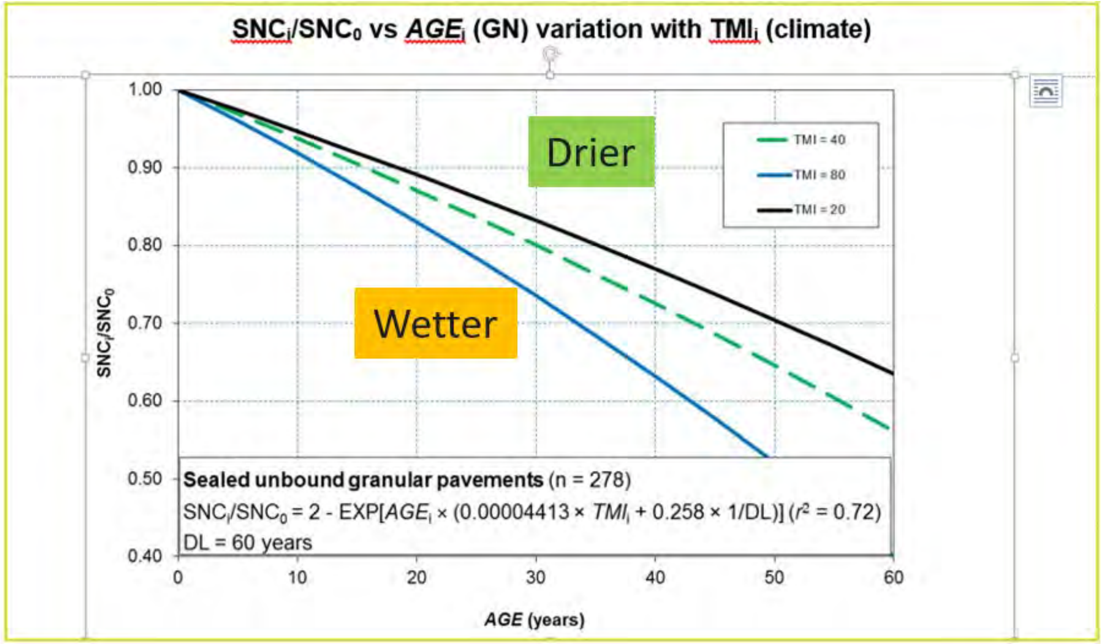


Oct 2022 events in Victoria



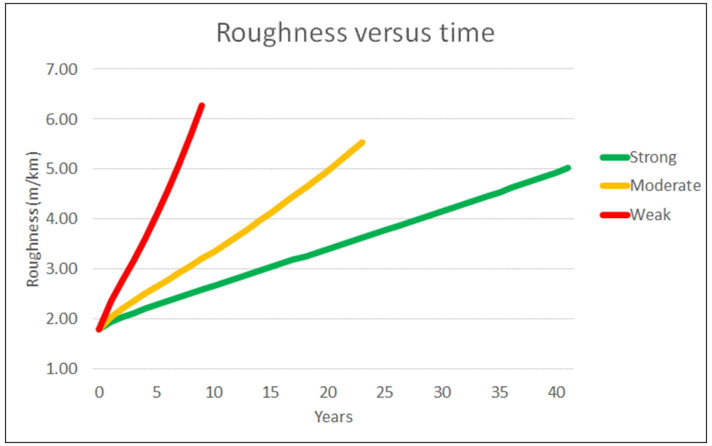
How does pavement strength and performance change with moisture risk for sealed LVR?

Ratio of current and initial pavement strength change with age and climate



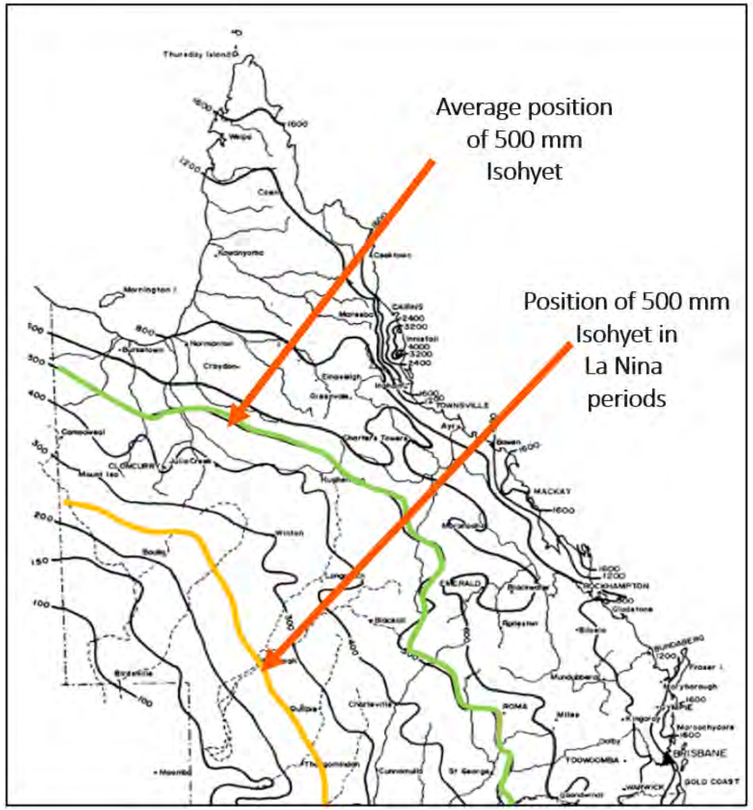
Impact of varying pavement materials, climate and drainage on rate of deterioration

Pavement moisture and drainage	Modified structural number (SNC)		
	Standard materials	Marginal materials	Non-standard materials
Dry, well-drained	5.1	5.1	3.2
Dry, poorly drained	5.0	3.1	3.1
Wet, well-drained	3.1	1.8	1.6
Wet, poorly drained	2.9	1.6	1.5

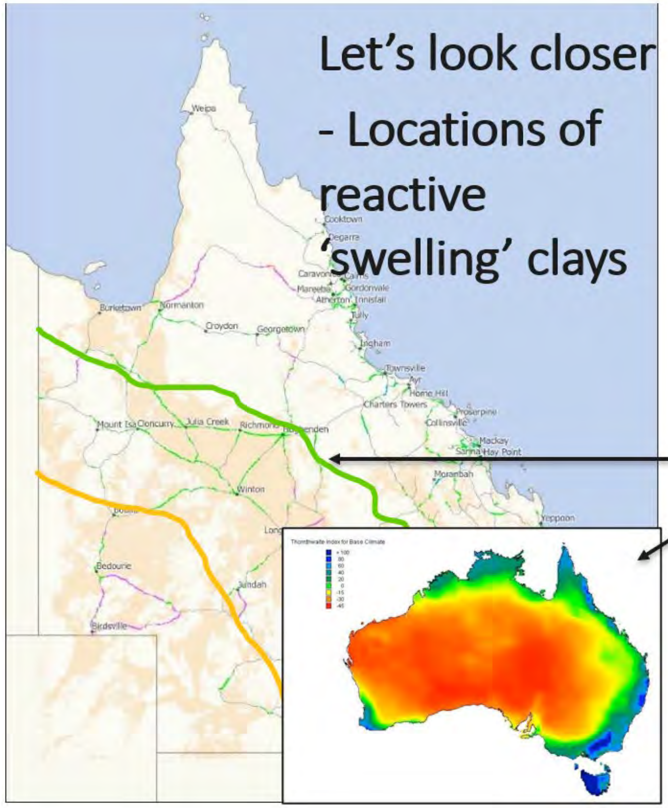


Long-term trends /cycles – lessons from history?

Western Queensland Best Practice



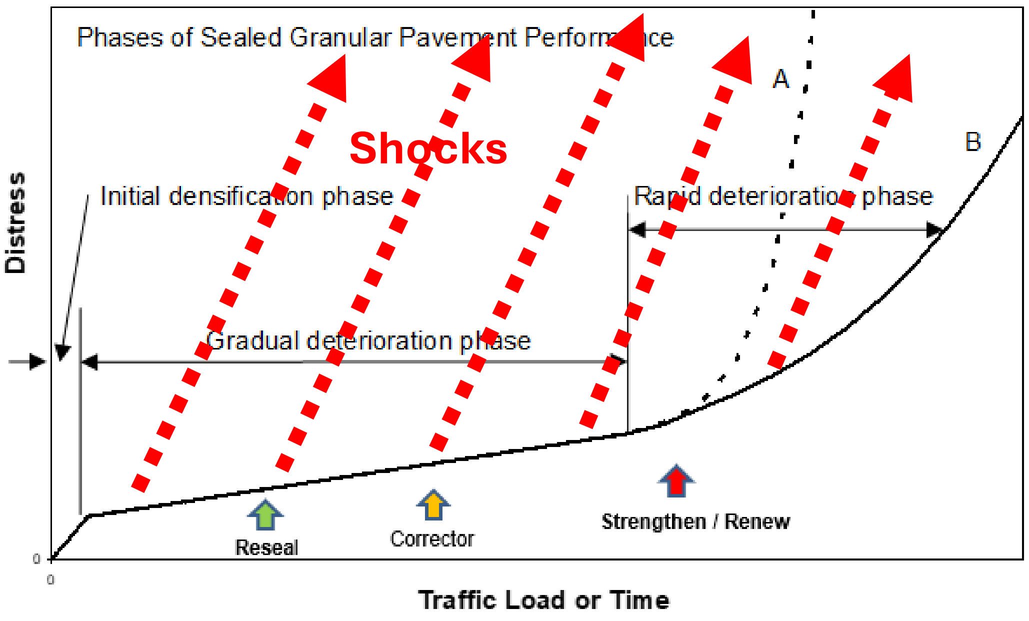
WQBP versus a less informed static view



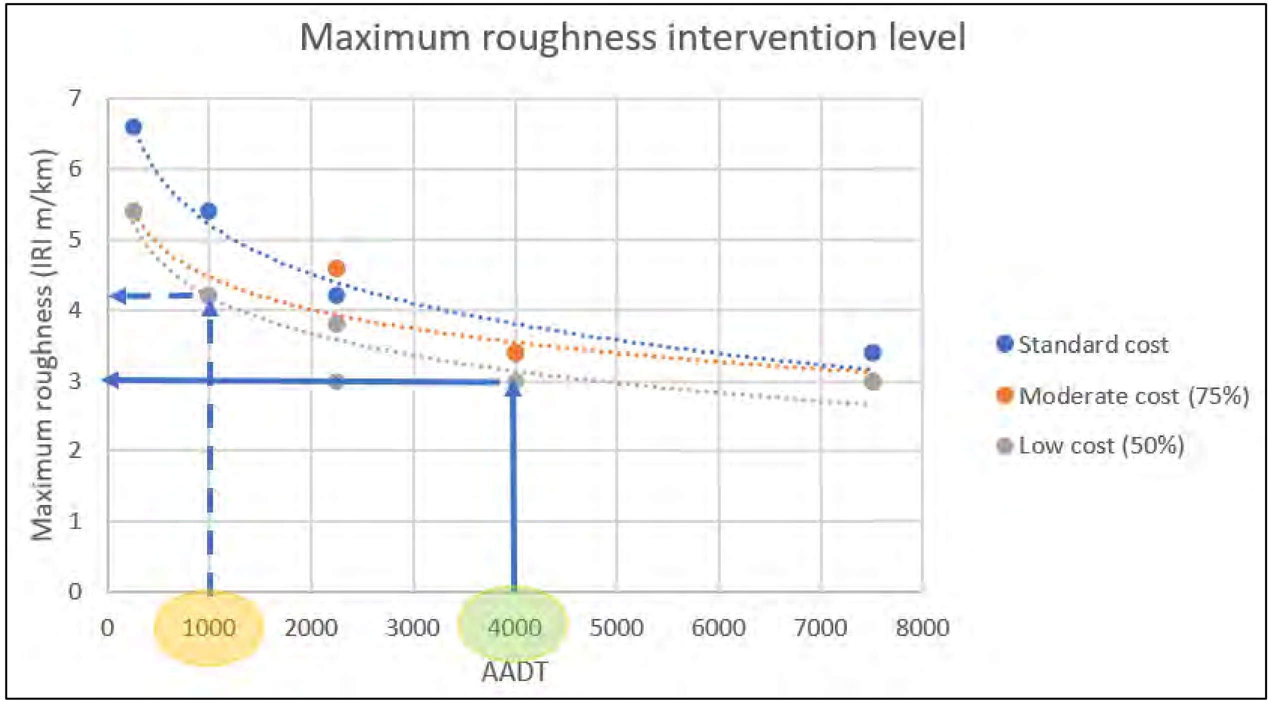
The static view
- Rainfall
- TMI

Predicting performance and treatment needs, retaining memory and adding solutions

Phases of sealed road deterioration and varying treatment responses, but be ready for climate related shocks



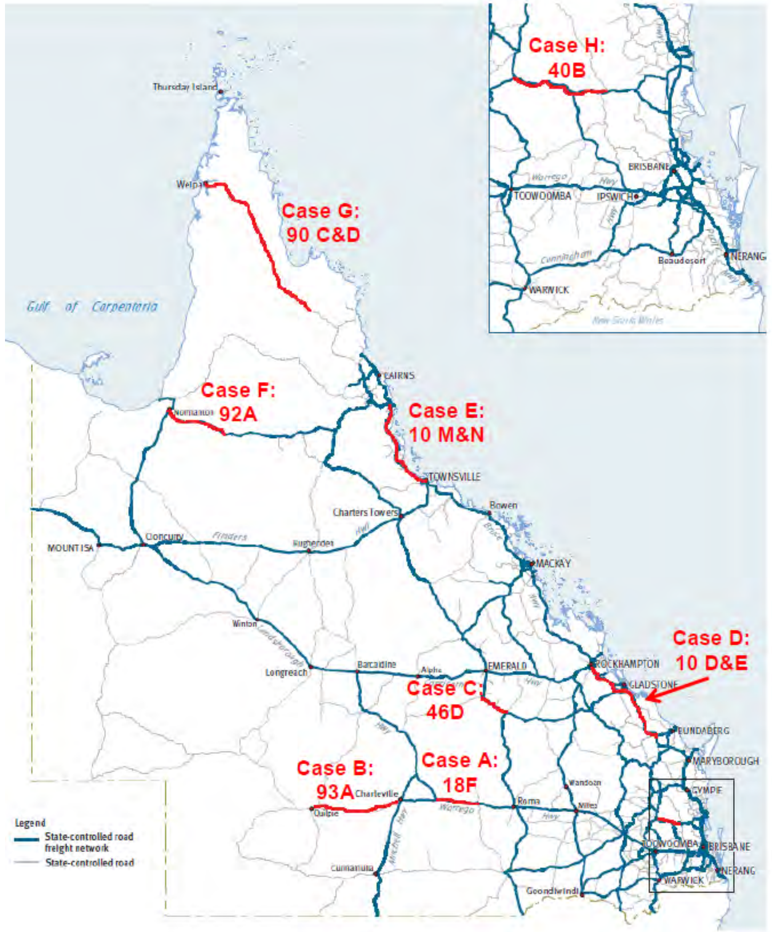
Augmenting stitch-in-time with lower cost regulation or corrector treatments on granular pavements where appropriate



4. Resilience and changing conditions for road infrastructure: A case study and some pointers

Queensland – Life Cycle Cost of rain & flood events

- Collected data on the rain/flood events and Transport Network Rehabilitation Program (2010/13)
- Developed analysis methodology & selection criteria
- Identified 7 case studies including background data
- Investigated gradual deterioration within different environments and recurrence cycles of extreme events
- Considered preventative 'stitch-in-time' and full resilience strategies as alternatives to 'business as usual/as-happened'
- Accounted for disruption, i.e. reduced access, lower speeds, during period of disruption and rebuilding

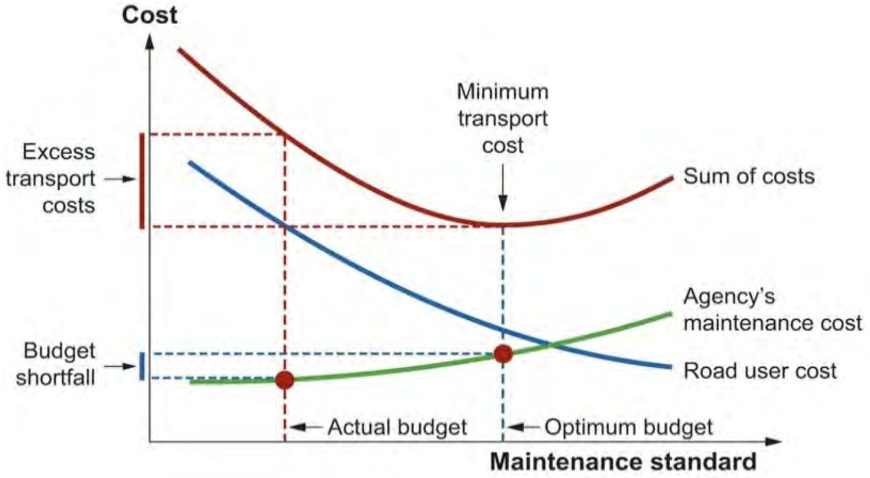


Results by Route Type, Option and Recurrence Interval (Present Value of Total Transport Costs)

Overall	Interval	BASE	OPTION 1 Full resilience	OPTION 2 Stitch in time
Major routes (10D,10E,10M,10N)	Long (25 yrs)	$30,159,251,649	$30,631,394,584	$30,003,411,162
	Normal	$30,497,428,885	$30,671,726,755	$30,192,697,534
	Short (5 yrs)	$31,418,134,627	$30,750,196,527	$30,621,676,989
Rural highways (18F, 46D)	Long (25 yrs)	$1,737,265,696	$2,005,934,221	$1,715,166,130
	Normal	$1,797,916,897	$2,006,348,858	$1,755,568,922
	Short (5 yrs)	$2,075,200,366	$2,044,291,592	$1,910,643,269
Development & remote roads (90C,90D,92A,93A)	Long (25 yrs)	$1,928,420,211	$1,880,938,155	$1,760,305,248
	Normal	$2,156,171,671	$1,919,133,580	$1,911,807,303
	Short (5 yrs)	$2,433,467,006	$1,958,448,306	$2,067,605,711
TOTAL	Long (25 yrs)	$33,824,937,556	$34,518,266,960	$33,478,882,540
	Normal	$34,451,517,452	$34,597,209,194	$33,860,073,759
	Short (5 yrs)	$35,926,802,000	$34,752,936,425	$34,599,925,969

Green	Lowest TTC
Orange	Mid TTC
Red	Highest TTC

Looking for 'Goldilocks'



Summary of findings

Stitch-in-time leads to savings (case studies only)

- Agency costs same or lower
- Reduced impact of rain/flood events

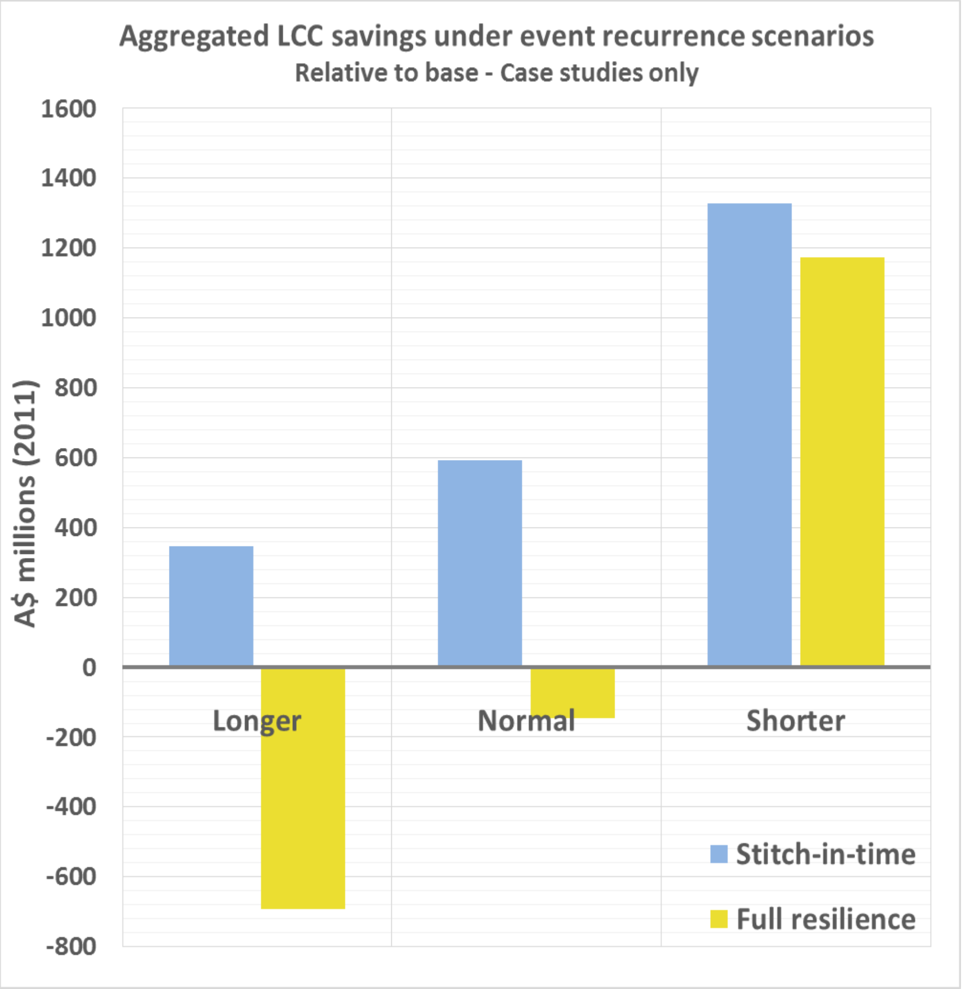
Full resilience generally not advantageous (case studies only)

- Very high agency costs, not recovered
- Potentially viable on higher order roads

Best for network

- Appropriate mix which maximises savings
- Net economic savings of $2.7 per additional $

Spend $6 billion ASAP to future proof



Lessons learnt from Queensland 2010–13 period

- Similar events are likely in the future
- Strategies must consider the future likelihood of major weather events
- Simple measures can prevent and mitigate many impacts
- Whilst results by case study are case specific, further modelling has shown:

Major routes	Rural highway network	Development roads and remote links
• benefit from high investment to create fully resilient pavements • considerable value in maintaining access	• need assessment for vulnerability • critical routes benefit from increased resilience • targeted investment	• too expensive to impart full resilience • important to maintain basic connectivity

Aim to avoid the 'boom-and-bust' cycle

In Summary: How can we respond?

Understand our climatic challenges, anticipate these and act

Apply and develop knowledge and technology:

- Asset management
- Pavement and materials
- Network planning and access management

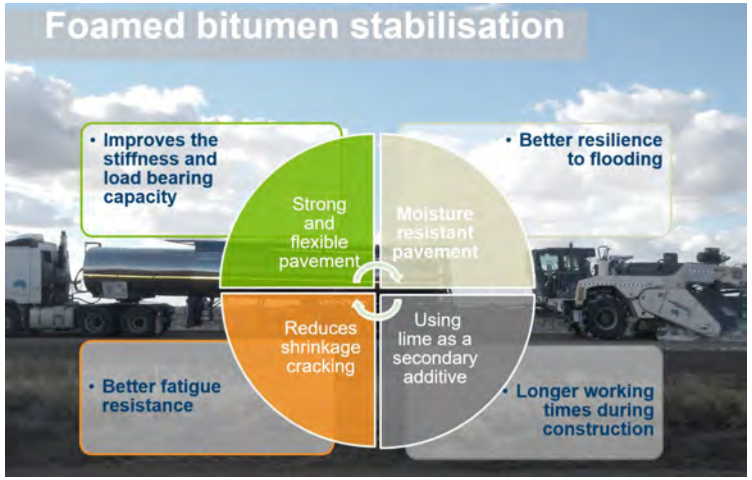
Continue to apply and improve planning and decision support frameworks and tools, and consider uncertainty

Appropriate funding

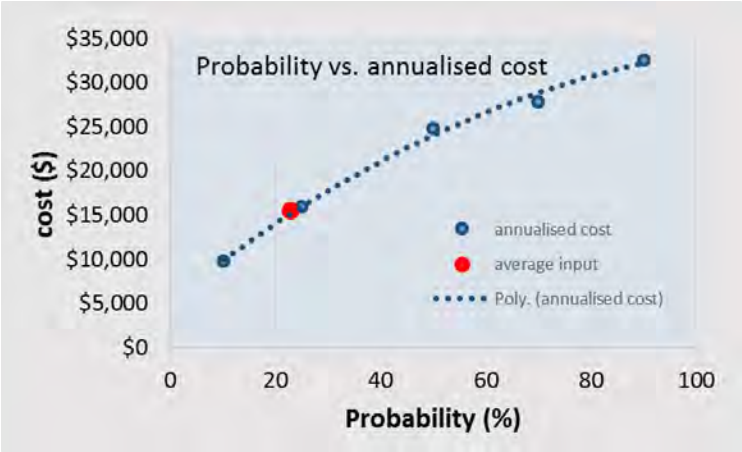
Deliver and be more ready and responsiveness

As a general rule, all of these plus 'Sharing with local and international partners'

Technology can help



Modelling with uncertainty



5. Raising awareness of further NTRO research projects

Circular economy
Sample of projects and outputs

- Best practice advice on recycled material use in road and railway infrastructure (Commonwealth) https://www.ntro.org.au/news-and-insights/arrb-report-to-guide-increased-recycled-material-use-in-road-and-rail
- Framework to incorporate bushfire resilience into road infrastructure (LGTRRIP)
- Sustainability Assessment Tool for Pavements (SAT4P) (NACOE/WARRIP)
- Practitioners Guide: Local Government Guidelines for Sustainable Road Construction Practices in WA (LGTRRIP)
- Sustainable Roads Through Fit-for-purpose Use of Available Materials: Evaluation Tool and User Guide (AP-T353-20 | Austroads) (Austroads)

SCAN ME TO READ

Resilience and asset investment modelling Sample of projects and outputs

- Accounting for Life-cycle Costing Implications and Network Performance Risks of Rain and Flood Events (NACOE)
- Identification of Residual Risk for each Element and Development of a Funding Allocation Methodology of Elements (NACOE)
- Prolonging the Life of Road Assets Under Increasing Demand: A Framework and Tools for Informing the Development and Justification of Asset Preservation and Renewal (Austroads) (AP-R649-21 | Austroads)
- Considerations for Sealing Local Government Roads in WA: User Guide & Technical Report (LGTRRIP) (Considerations for Sealing Local Government Roads in WA | WARRIP)
- Austroads Road Deterioration Model Update: Deflection (AP-T367-23 | Austroads)

SCAN ME TO READ

Selection of NTRO ongoing research projects

- New Generation iPAVe: Optimising its use for Road Asset Management (NACOE)
- Impact Assessment of the Introduction of Low and Zero Emission Heavy Vehicles on Road and Transport Infrastructure (NACOE)
- Improved model for seal life estimates in asset management and updating of Element 17 Management Plan (NACOE)
- Planning for Infrastructure Vulnerability Due to Climate Change (WARRIP): Planning for Infrastructure Vulnerability due to Climate Change | WARRIP)
- Updating the Assessment of Remaining Service Life of Pavements (Austroads: Projects | Austroads)
- Assessing Impacts of Heavy Vehicle Increased Axle Loads on Pavements (Austroads: Projects | Austroads)

SCAN ME TO READ

Case Study: Sustainable and Innovative Road Safety Project

Do compact roundabouts present a more cost-effective, safe and sustainable treatment for addressing intersection crashes which are major contributors to severe road trauma?

Project Team

- Mornington Peninsula Shire Council: Mathew McQuinn
- NTRO: Karen Cogo, Dr Sepehr G Dehkordi
- Corben Consulting: Dr Bruce Corben
- Real Time Traffic: Justin Lu

Photo courtesy: Real Time Traffic

Myers Road and Hendersons Road, Bittern, Vic

Previous Conditions

Background

- Cross intersection in semi-rural environment
- Mixed speed limits on each leg
- Blackspot and had federal funding

Benefits and Summary

1. **Environmental benefits**
   - Smaller footprint, less encroachment on land, and on flora and fauna
   - Utilities relocation minimised, less demolition waste, less construction materials.

2. **Performance benefits**

   Reduction in approach speeds and approach angles, ultimately reduces crash severity and serious road trauma.

3. **Cost benefits**
   - Speed platforms and cushions eliminate the need for a reverse curve and provide an opportunity to reduce the central island diameter.
   - Quicker construction time.

4. **Safety benefits:**
   - Speeds now consistent with Safe System / human injury tolerance (~27km/h), using kinetic energy model.

Summary

- Compact roundabouts have the potential to support the long-term goal of Vision Zero.
- It is the ***management of impact speeds***, and not necessarily the reduction of speed limits, that will have the greatest effect on minimising harm
- The project used existing intersection footprint to achieve the same safety outcome with reduced material, time and cost.

6. Concluding remarks

Rethink – Rebuild – Resilient

1. Reimagine how materials flow through our networks

   Can we repurpose or reuse existing materials

2. Rebuild smarter

   Using what we already have to build smarter and reduce waste

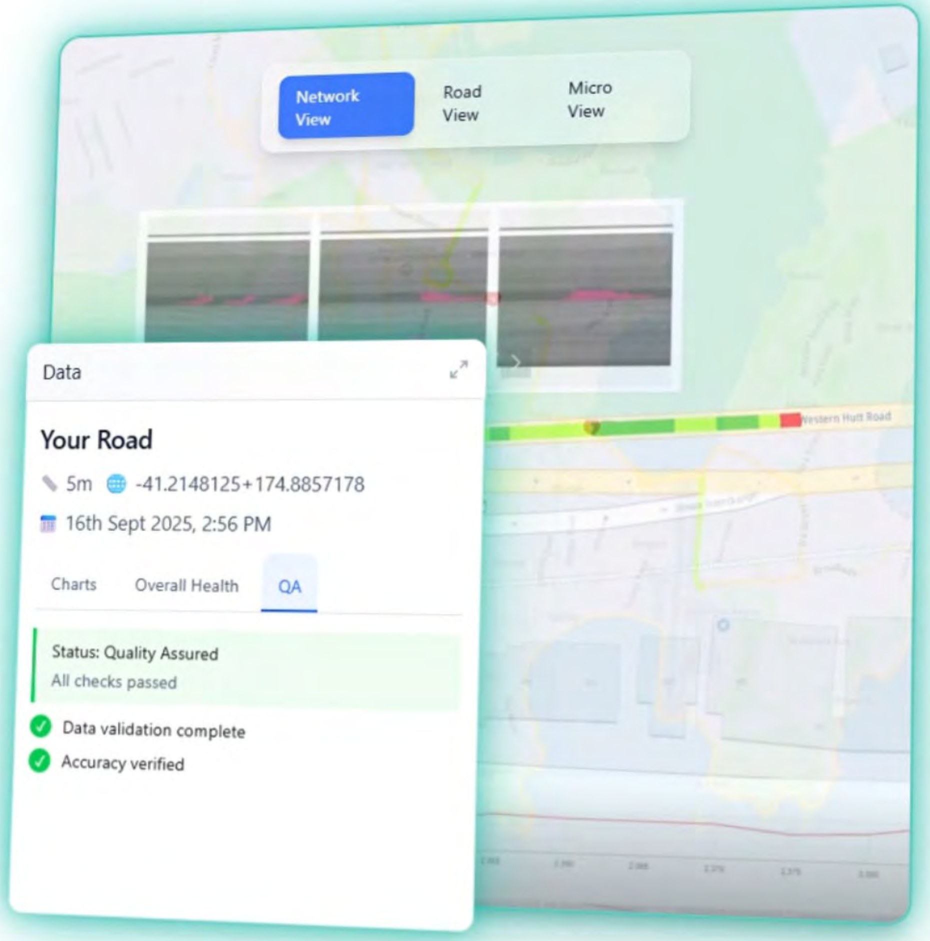
3. Resilient Roads

   Design and maintain roads that recover, adapt and endure — circular by design

Tools to Support Better Road Performance

1 Digital Tools for Smarter Decisions

- Asset vulnerability / risk assessment
- Road lifecycle modelling
- Asset condition forecasting
- Decision-support dashboards



What you can do now

1. Review procurement frameworks
2. Identify upcoming projects to trial circular options
3. Connect with NTRO for support and case studies
4. Apply for federal / state resilience funding

Open Q&A / Discussion

THANK YOU

We exist to help your Council deliver safer, smarter, and more resilient roads.

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