

Local roads special issue

Local government is responsible for 85% of the Australian road network. This special issue of *Briefing* focusses on a range of road projects initiated by and for local government. On page 2 is an article describing a program being undertaken by Mornington Peninsula Shire to improve road safety. Pages 4 to 9 contain summaries of papers to be presented at a Regional Symposium on local roads to be held in Ballarat on 24-25 July. Pages 10 to 12 describe some of the many projects being undertaken at ARRB to improve the quality and operation of these roads.



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Issue 134 June 2012

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Contents

Issue 134 June 2012

Safer speeds on the Peninsula	2
Briefing by email	2
The 29th ARRB Regional Symposium	4
Austrorads ARRB partnership research for local government	4
Asset management software applications to assist decision making	5
25th ARRB Conference	5
Developments in bitumen and polymer modified binders	6
Application of LRDS for long term strategic planning	6
Deciding which trucks can use which roads	7
Recent developments in road design	8
Overview of rural and community road safety	8
How long will your bridges last?	9
Other Symposium presentations	9
Local roads deterioration models win award	10
Local government reminder	10
Pavement management in the City of Marion	11
ROMAN II's first birthday	11
Measuring pavement condition in the City of Greater Geelong	12
Obtaining maximum value from road data	12
ARRB gives 800 students free helmets	13
Conferences	13
Pavement asset research in the west	14
New Directors	14
ARRB delivers road safety audit training in Manila	15
Australian-first trial on Midland Highway	15
Improving road maintenance in Indonesia	16
TMR Metropolitan Region's network analysed	17
Want to know what that means?	17
ARRB Journal turns 50	18
New staff	18
Knowledge Transfer	19

Safer speeds on the Peninsula

The Mornington Peninsula Shire, an outer fringe municipality of the Melbourne metropolitan area is trialling lower speed limits on both local rural roads and in a residential area with the aim of reducing the level of road trauma as part of its road safety strategy – Peninsula DriveSafe.

ARRB has been engaged to evaluate the trial to determine if road safety benefits can be gained and importantly, to measure the level of community acceptance of reducing the speed limits. The Victorian Transport Accident Commission (TAC) has provided substantial support for the project by contributing funds towards the evaluation of the trial.

There is still widespread apprehension about the reduction of speed limits at the political level and with some road users. The road agencies are caught between trying to balance mobility needs whilst achieving safer road networks. Significant challenges were overcome to obtain the necessary approvals for the speed limit reductions and there is now an opportunity to gain necessary evidence to allay some of these concerns.

The aim of the Peninsula SaferSpeeds project is to target high crash risk areas as a further measure to the current crash risk assessment based infrastructure improvement and crash countermeasure



Photo: Mornington Peninsula Shire

The Peninsula SaferSpeeds project launch for the residential 40 Area speed limit trial at Rosebud. Left to right: Councillor Frank Martin – Mayor, Doug Bradbrook – Traffic & Road Safety Strategist MPS, Carolyn Bradshaw – ARRB Group, Jessica Truong – Project Manager, Road Safety TAC, Councillor David Gibb – ward councillor for Rosebud, Robin Tiffany – Road Safety Coordinator MPS.

Briefing by email?

In the interests of sustainable environmental practice ARRB Group is reviewing delivery methods for its publications.

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programs. The Shire had identified that their lower standard sealed rural roads had high crash rates compared to other road types.

Many of the serious injuries and fatalities resulted from crashes involving single vehicles losing control and hitting trees. Also, many of the Shire's residential precincts had an alarmingly high incidence of pedestrian and cyclist crashes involving vehicles.

Research reported by ARRB shows that a significant reduction in crashes can occur with only a small decrease in travel speeds. Based on this evidence and to complement the Shire's current safety initiatives it has introduced speed limit reductions from the existing default 100 km/h to both 80 and 90 km/h speed limits on 15 local rural roads in the southern part of the Shire.

A 40 km/h area speed limit is replacing the existing default 50 km/h in a residential precinct of Rosebud with an area of approximately 2 square km including approximately 3,500 dwellings.

The Shire's Traffic & Road Safety team prepared the speed limit proposals for VicRoads approval following consultation with Victoria Police. Community communication strategies were also a key part of the project implementation plan involving media and providing community events.

A baseline survey of community attitudes and of vehicle travel speeds has been completed by ARRB prior to the speed limit changes. Preliminary assessment of this survey found 80% community support for the project prior to the new signs being installed. A post-change survey is scheduled in 12 months to allow the change to driver behaviour and community attitudes to bed in.

The development of the community questionnaire and engagement of a market research company to do the telephone



Photo: J. Best

surveys was completed by ARRB to ensure that credible results would be achieved. In association with Monash University Accident Research Centre (MUARC) a sample of trips are also being surveyed pre and post-change to evaluate changes to travel times.

For further information and updates on the project refer to the ARRB and the Mornington Peninsula Shire websites.

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29th ARRB Regional Symposium 24-25 July, Ballarat, Victoria



The Symposium will concentrate on recent research findings and local road applications. Topics will include:

- The Austroads research program and what it can do for local government
- Pavement asset management fundamentals
- Asset management software applications to assist decision making
- Pavement performance modelling and the local roads deterioration study (LRDS)
- Application of the LRDS models in long term strategic planning
- Developments in bitumens and binders
- How long will your concrete bridges last?
- Managing parking issues in small towns – when to consider introducing user pay
- Performance based standards (PBS) route assessment tool
- Recent developments in road design
- Current developments in rural and community road safety.

The event is restricted to ARRB members and government agencies, including:

- local government
- state road authorities
- other government bodies such as educational institutions.

Further information, including venue and accommodation details, is available on the website: www.arrb.com.au/RegionalSymposium2012.



Photo: J. Best

29th ARRB Regional Symposium

The symposium will be held on Tuesday, 24 July and Wednesday, 25 July 2012 at the University of Ballarat, Mt Helen. On pages 4 to 9 are a series of short articles on papers to be presented. All PowerPoint presentations will be available from 26 July at www.arrb.com.au/RegionalSymposium2012



Austroads ARRB partnership research for local government

Photo: K. Neaylon

The national strategic research program addresses five key areas: bituminous surfacings, pavement technology, asset management, road safety engineering and network operations. What can this program of research offer local government?

Bituminous surfacings research covers the areas of bitumen and polymer modified binders, asphalt and sprayed seals. As an example, bitumen extenders and alternatives to bitumen are being investigated for road surfacings. One promising product is tall oil pitch (an organic waste product produced in paper manufacturing) which may extend bitumen by between 7 to 10% and a field trial has been established. In another field trial, current formulations of all Austroads polymer modified binder (PMB) classes

have been laid side-by-side together with a bitumen control, to enable their performance to be monitored and ranked in two real-life situations.

Pavement technology research continues to focus on the response of flexible pavements to changing vehicle loads and new-generation heavy vehicles. A standard test involving use of a new large format wheel-tracker for testing rutting in granular bases is under development. Additionally work on laboratory characterisation of cemented materials is progressing. Field trials of foamed bitumen stabilised pavements are underway.

Asset management provides an overarching framework for implementation of the detailed technical investigations of the other research areas. One recent project involved development of a new index that assesses the road roughness experienced by heavy vehicles for use in triggering pavement rehabilitation. In another project, a mobile rig is being developed to measure horizontal tyre forces and road surface wear from a turning heavy vehicle.

In **road safety** the key focus is to assist development of the road and the roadside environment in order to reduce the incidence and severity of crashes as part of

the Safe System approach. As an example, the use of rural gateway treatments for speed management has a considerable safety benefit. Current research on roadside safety involves investigation of three key areas; roadside hazard management, selection and placement of safety barriers, and selection of clear zones.

Network operations research is targeted at improving the productivity and reliability of the road network in moving people and goods. A project on the application of the network operations planning framework to assist with congestion management and integrated land use and transport is a good example. Similarly, implementing national best practice for traffic control at worksites is very pertinent for local government.

Research project findings will inform future updates of the Austroads Guides which are available for free download by local government from www.austroads.com.au

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Photo: R. Yeo



Asset management software applications to assist decision making

Road asset management software which can store network information and data can improve an agency's understanding of its assets. An agency can more accurately establish the value of its network and develop maintenance programs based on objective assessments, which can be a useful tool to improve decision making.

The Road Assessment and Maintenance Management (RAMM) system from New Zealand incorporates a suite of applications to provide a powerful road asset management software solution. It is a database in which users can define

the road network and store the condition of the network and associated assets.

This information can be easily extracted for reporting purposes and can also be used in the Works Selection Tool (WST). The WST was developed to assist with the selection and prioritisation of immediate works on the road network and would be a useful application for road managers looking to screen their network for candidate treatment sites.



The paper will include a demonstration of the RAMM system and outline the RAMM suite of applications and WST interface and workflow.

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23-26 September 2012
 Pan Pacific Hotel
 Perth, Western Australia



The Conference will explore how the results of transport research and practical experience support informed decision-making, and will include two plenary sessions and a joint third session with the Australasian Transport Research Forum (ATRF).

Keynote and plenary speakers include:

- Mr Menno Hennevel, Managing Director of Main Roads WA – Keynote address at the opening ceremony.
- Mr Steve Phillips - Secretary General, Forum of European National Highway Research Laboratories (FEHRL).
- Mr David Simon, Chairman of the Australian Trucking Association (ATA) – *Improve productivity or perish!*
- Mr Neil Aplin, Director of Aplinquill – *Balancing sustainability, road safety, network performance and community expectations.*
- Dr Fred Affleck, Chairman of the Freight and Logistics Council of Western Australia – *Shaping cities: The role of transport planning in the future.*
- Mr Lars Nilsson - Environmental Director, Swedish Transport Administration – *Balancing sustainability, road safety, network performance and community expectations.*

All delegates will receive two free issues of the *Road and Transport Research* journal following the conferences. The free issues will be delivered as downloadable pdf files via the ARRB website and password access.

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Photos: K. Neaylon

Developments in bitumen and polymer modified binders

Bitumen is the key ingredient in road surfacing, used in both hot mix asphalt and in sprayed sealing. However, bitumen refineries in Australia are continuing to close, and most bitumen used in Australia is now coming from Singapore, Thailand and possibly even Korea. What does this mean for us? Why is the Australian standard for bitumen different to the Asian standard?

The Asian specification is based on a penetration test done at room temperature, whilst the Australian specification is based on a bitumen flow test done at a higher temperature common to most Australian road pavements. This is a property that directly suits Australian conditions. Penetration grade bitumen is not inferior bitumen, it is just graded in a way that does not reflect how it will perform here.

It is still possible (but requires considerable effort) for competent importers to analyse the available crudes and refineries to find particular Asian refined bitumens

that overlap the Australian specification requirements, and thus meet Australian needs.

What do we do when global demand for finite bitumen resources outstrips global supply, and market forces act so that bitumen is increasingly less affordable to use on Australia's sealed road network? An organic waste product from the paper manufacturing industry, tall oil pitch, has been laboratory tested and recently was road trialled at a location not far from Bendigo, to test whether this product can be used to extend current bitumen volumes (see page 15).

Polymer modifiers are commonly added to bitumen to make polymer modified binders, or PMBs, which then creates a bituminous binder able to cope with the strains of increased traffic loading. The PMB specification has recently been changed. There are now two Austroads PMB field trials established to monitor and rank the field performance of the current generation of Australian PMBs.

ARRB has also been studying PMB morphology to see whether this can account for some of the variability in laboratory PMB test results. A recent study has also been completed on the segregation and degradation of commercially available PMBs, with controversial results. The Austroads report will be published shortly.

There are two tests specified in Australia that measure whether the polymer stays dispersed in PMBs (Segregation and Ease of Remixing). A different test is specified in Europe (Storage Stability). Current research work is aiming to determine which of the available Australian and European tests is best at predicting whether polymer separation of PMB binders will occur when materials are mixed under typical conditions.

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Application of the local roads deterioration study for long term strategic planning

This presentation will discuss the role of asset strategies in ensuring:

- an integrated approach to the management of the capacity, condition and use of assets
- a consistent approach across all elements of the network
- transparency and auditable accountability to the community for the asset management performance of road authorities.

As an example of how software can be used for management of road assets, this session will examine the dTIMS software which is part of the ROMAN II package being implemented for local government agencies in Western Australia.

The session will describe how the software can:

- model performance through the use of the local roads deterioration study

- develop a detailed forward works program and maintenance plans
- compare different maintenance policies/strategies
- estimate budgetary requirements to maintain the target level of service
- optimise the use of available budget.

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Deciding which trucks can use which roads



Photo: A. Ritzinger

The process of determining network access for next generation heavy vehicles can be a daunting task for road transport professionals within local government. Over 80% of Australia's road network is managed by local government, including in many cases the 'first and last kilometre' of potential high-productivity vehicle trips.

Local government often operates with limited resources available to assess route applications for next-generation freight vehicles, and can also be under pressure from heavy vehicle operators for increased network access, as well as managing public resistance to increased use of larger trucks.

While high-level guidelines such as the National Transport Commission's Performance Based Standards (PBS) Network Classification Guidelines have existed since 2007, the process of assessing routes remains challenging and time consuming. There is a strong need for an automated tool to ease the burden of this undertaking.

ARRB has addressed this need by developing the PBS Route Assessment Tool (RAT) in collaboration with the

Municipal Association of Victoria (MAV). The PBS RAT is a software-based website tool for local government practitioners, designed to allow heavy vehicle route assessments to be completed in line with route classification guidelines developed by ARRB.

The tool allows users to enter data on a specific route of interest, and assess the infrastructure's ability to facilitate the safe and efficient operation of heavy vehicles. The tool provides a detailed PBS classification for each segment of the route. By conducting the assessment in this manner, local government can clearly identify the most restrictive elements of the route according to the classification guidelines.

Use of the tool will result in a consistent application of a heavy vehicle route assessment process across local governments, that will facilitate certainty of operations for industry and ensure that heavy vehicles that are granted access to local roads are able to safely operate in that environment. It is hoped the use of an independent approach to heavy vehicle route assessment based upon

local government specific assessment guidelines will assist municipalities caught in this often difficult situation.

In order to ensure that the tool will be of relevance and use to local government, ARRB and the MAV have established a Technical Advisory Group made up of the funding agencies, local government engineers and industry stakeholders, including the recently formed National Heavy Vehicle Regulator, that will guide the system development.

The PBS RAT is currently being trialled. With high levels of interest and enthusiasm for the project from jurisdictions nationally, future developments may include the wider availability of the online tool for use by state and local governments across Australia.

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Recent developments in road design

Austrroads *Guide to Road Design* (GRD) provides the main source of information and guidance to road designers in Australia. ARRB plays a key role in supporting the development and review of this Guide.

The GRD comprises eight parts, with some having sub-parts. The Guides have been developed through the collaboration of road agencies, including local government, across Australia and New Zealand. It brings together the results of research and assembly of the best practices into a consolidated, user-friendly guide.

The parts are regularly updated through an extensive review process, to keep the information current and relevant for the road designer. The parts currently under review are:

Part 4 – Intersections (including Parts 4A, 4B and 4C) has a focus on providing greater consistency in intersection layouts and the outcomes of Austrroads projects relating to cyclists at roundabouts and intersection sight distances relating to car and truck acceptance gaps.

Part 5 – Drainage has undergone an extensive review, to incorporate more information and worked examples, covering the catchment analysis, environmental issues, hydrologic assessments, drainage of road surfaces,

aquaplaning, open channels, underground drainage, culverts, and floodways. There are worked examples for many of the areas covered and the designer will be able to see how the theories are put into practice.

Part 6 – Roadside Design, Safety and Barriers, is examining the use of roadside safety barriers, roadside environments, taking in the latest research from overseas, notably from the American Association of State Highway and Transportation Officials (AASHTO).

There are also several research projects underway - the incorporation of Safe System principles into the guides and a study of the geometry of rural roads

The Safe Systems approach, has been adopted by the Australian Transport Council and incorporated into Australia's Road Safety Strategy 2011 - 20. This approach has the aim of preventing road fatalities and serious injuries. It recognises that humans will make mistakes, but aims to create a road transport system in which these mistakes do not result in death, or serious injury. The road designer plays a key role in developing solutions to meet this philosophy.

The rural road geometry study is investigating geometric elements, e.g. horizontal curves and intersection



Photo: W. Hore-Lacy

alignment, that are experiencing crashes and determining the relationship of the crashes to the geometric element.

Feedback is welcomed through the Austrroads website <https://www.onlinepublications.austrroads.com.au/> or to:

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Overview of rural and community road safety

This session will aim to provide an overview of recent developments in road safety that are relevant to current and future practice. Areas to be covered will include:

- the National Road Safety Strategy and the role of state and local government in achieving its objectives
- latest information on crashes on local government roads in Australia
- current video/GPS systems for capturing data on roads and roadsides
- the AusRAP and Netrisk procedures for aggregating this data and presenting it in an easily understood, actionable format
- current work identifying the nature of run-off-road crashes and the implications for the provision of clear zones and safety barriers.

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Photo: P. Cairney

How long will your concrete bridges last?

Two mechanisms that can cause serious deterioration problems for concrete and affect the integrity and load capacity of bridge structures are corrosion of reinforcement and alkali-aggregate reaction (AAR), the effects of which are illustrated in the photographs.

The corrosion is related largely to the quality and thickness of the cover concrete; the properties of the cementitious phase, such as its porosity and chloride binding capacity having paramount effects.

The AAR can lead to serious cracking of concrete and deterioration of its engineering properties. The development of AAR in concrete can be related to both the nature of the cementitious phase and that of the coarse and fine aggregate phases.

The presence of AAR-related cracking can promote other durability problems in the structure, by allowing aggressive agents to penetrate into concrete and promote the corrosion of reinforcement.



Delamination of beam soffit and cracking of column caused by chloride-induced corrosion.

The paper will discuss prediction/progress of these deterioration mechanisms, allowing an estimation of how long the structure would last, if no intervention were to be applied. Ways to minimise their effects in order to increase the service life of concrete bridge structures will also be discussed.

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Photos: A. Shayan

Bridge column suffering from both AAR and reinforcement corrosion

Other Symposium presentations

Tim Martin will present on the *Pavement performance modelling and the local roads deterioration study (LRDS)*. An article describing this study in more detail is on page 10.

Jon Roberts will present on *The fundamentals of road pavement asset management*. This topic will be explored in the context of both collecting the right data to inform 'current status' decision making and applying software applications to inform long-term strategic planning. A broad appreciation of the structure and application of road pavement asset management to aid sealed and unsealed local road management will be discussed and will provide an understanding of the need to analyse organisational needs to achieve sustainable practical use of road pavement management.

Larry Schneider's presentation will focus on parking and transport issues facing rural towns. Some of the issues covered will relate to:

- managing the perception of a lack of parking



Photo: J. Best

- employee versus short-term parking
- managing spillover into residential areas
- cost-effective enforcement
- triggers for pay parking
- efficient use of parking bays
- seasonal parking shortfalls
- location of future parking facilities
- cash in lieu.

These will assist in clarifying the strengths, weaknesses, opportunities and threats of current parking practices in a town. The presentation will also explore methods and procedures for parking management and control and provide a brief overview of technology options including in-ground sensors, pay and display and multibay systems.



Photo: E. Winkler

Local roads deterioration models win award

The project which developed the first Australian local road deterioration models has received an Excellence Award from IPWEA Victoria. Involving a collaboration of more than 230 road agencies, the models were derived from analysing the findings of a long term monitoring strategy covering over 500 sealed and 100 unsealed local road sites in various traffic and climatic environments across Australia.

Until now most asset management systems (AMS) in Australia were based on internationally derived deterioration models adapted to suit local conditions but with limited success. As a result, asset managers have been shifting away from empirical and data based advanced AMS and have relied increasingly on experienced practitioners.

For the first time, asset managers have access to a range of evidence based deterioration models to assist in making decisions about maintenance programs for local roads. The extent of scientific rigour applied to the data collection and analysis has enabled these models to be unique, rigorous and robust.

The models cover sealed (sprayed seal and asphalt surfacing) and unsealed

local road types and would be suitable for incorporation into an existing AMS. This should encourage and support asset managers to move towards using advanced asset management with systems and models tailored to their local conditions and practices.

The deterioration models for:

- unsealed roads include roughness deterioration, gravel loss and transverse shape loss to the pavement
- sealed roads include surface cracking, rutting, structural strength and roughness.

To better assist Councils with their application, the models have been incorporated into an MS Excel tool. The models have since been implemented by a number of Councils for maintenance planning, e.g. Moorabool Shire in Victoria. The successes seen so far have led to a plan for wide implementation across local government road authorities in Western Australia through the ROMAN II AMS scheduled for 2012.

The models when implemented ensure AMS is more effective and efficient. Research has shown that implementing

an effective AMS can result in annual maintenance savings of up to 30% through improved management and judicious allocation of resources.

The study commenced in 2000 and was first delivered in regional instalments, with the final completion of the national study in May 2011. Although the consolidated cost of the study was approximately \$4.5 million, each organisation only contributed a relatively small amount of around \$1,500 per year per site over the five year monitoring period.

In pooling the funds and associated work into a single significant research program, all participants effectively benefited from the \$4.5 million national research program, delivered by highly experienced research engineers with rigour and high quality standards for a minimal outlay. From the cost benefit point of view, \$4.5 million is a small investment in an estimated annual expenditure of \$1.6 billion on local road maintenance.

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Local government reminder

All local government organisations can access all Austroads publications including the Guides electronically for free. For further information please

email austroads@austrroads.com.au.
Hard copy publications still need to be purchased.





Photo: E. Winkler

Pavement management in the City of Marion

The City of Marion in South Australia has engaged ARRB to assist in implementing a new pavement management system to further improve their asset management practices. ARRB proposed a number of approaches to best cater for the City's requirements. The City chose to adopt the option which included two new software systems - RAMM, created by RAMM Software Limited (RSL) in New Zealand and dTIMS, created by Deightons in Canada. This software combination is also the package which the ROMAN II project uses for local governments in Western Australia.

The City's staff have been heavily involved in the implementation process and are pleased with the partnership approach ARRB has brought to the project. A number of workshops have been held with City staff to ensure that all key requirements have been met and any issues addressed. The project involves a number of deliverables:

- level of service establishment for the road network
- data collection of road and kerbing condition including high speed data
- falling weight deflectometer (FWD) testing on a selection of roads

- update of the road inventory in GIS, involving a full re-digitisation
- implementation of RAMM including training sessions with staff
- dTIMS modelling
- renewal, maintenance and operational plans
- material recommendations
- support services
- staff training
- assistance with works selection tools to derive the forward works program.

The support services (which will be based from the ARRB Melbourne office) will provide technical and software support for the City of Marion users through phone or email support. A website is also being developed which will provide a document database, support ticket tracking and other related information which is easily accessible by the City and ARRB staff.

Along with the support services, ARRB is running training workshops for the City staff which will combine technical asset management practices and how to use the RAMM software. It is envisaged that through these training courses the City staff will become sustainable in both RAMM, optimised decision making, and in asset management principles.

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ROMAN II's first birthday

On 12 May, the ROMAN II team celebrated the 1 year anniversary of 'going live' in Western Australia. ROMAN II gives a uniform system for the State's local governments to manage their road assets. By having a common system, the local governments collectively gain advantages through sharing knowledge and by having standard practices. Uptake of the new system has been excellent and has exceeded expectations with 134 of the 140 local governments in WA participating.

Introduction of the new system has invigorated pavement management

practice in many local governments. Many are already making financial decisions based on the output from their database. The majority used the first year of the project to update their databases for both condition and inventory of their road networks. Some have already started progressing past this stage and are looking to update and include assets in RAMM other than just their road network, for example footpaths and signs.

A number of local governments are also taking advantage of their updated data to run dTIMS to create twenty year recommended works programs for their road networks. This has occurred faster than was originally envisaged for the



project and it is a great step forward in asset management for the region.

ARRB's Network Survey Vehicles have been busy collecting automated road condition data for councils across Western Australia. ARRB has already collected, assessed and uploaded over 2,500 km of urban and 1,300 km of rural network for nine councils.

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Measuring pavement condition in the City of Greater Geelong



Across the summer of 2011-2012, ARRB's data collection team were hard at work collecting the City of Greater Geelong's (CoGG) pavement condition data using their Hawkeye 2000 Network Survey Vehicle. The council is one of the biggest (and most complex) municipal road networks in Victoria, spanning nearly 2100 km of sealed roads across the 1245 square kilometre land area surrounding Victoria's second biggest city.

Photo: W. Hore-Lacy

complexities of the road network and produce a forward maintenance works program.

ARRB was able to team up with the Council to collect the raw data that drives this maintenance program. The Hawkeye system uses the latest laser, camera and positioning technologies to produce a range of outputs for SMEC such as roughness, rutting, cracking, patching and other surface defects. As well as being an industry leader in the field of automated road data collection, ARRB has extensive experience with the SMEC system, allowing for hassle-free integration of data for the council.

For all pavement management systems, the quality of this data is critical to achieving a successful pavement management outcome.

The CoGG engineers are tasked with balancing the needs of a complex urban environment within the Geelong CBD, together with the access needs of its rural constituents. The Geelong area also has a strong manufacturing industry with its associated heavy vehicle use, as well as

the holiday towns of Barwon Heads, St Leonards and Queenscliff with their more intermediate traffic flows.

To assist the council's engineers, CoGG uses the SMEC pavement management software which helps model the

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Obtaining maximum value from road data

Since 2004, ARRB Group has completed network surveys for VicRoads using the Hawkeye 2000 platform. These surveys, collected over a two year cycle, include all seven regions of the VicRoads network and total approximately 27,000 km of the state's roads.

This data provides information regarding pavement roughness, rutting and texture, along with a comparison of previous surveys. Detailed knowledge of pavement behaviour throughout its life-cycle allows VicRoads to more effectively maintain its extensive network.

Although primarily collected for pavement life-cycle management, the network survey data is being used for additional assessment. An example is the work recently completed in the Metro North West region regarding assessment of non-pavement assets.

Using the original data set, ARRB evaluated the condition of over 3,800 barriers and 25,000 signs for VicRoads in the Metro North West region alone.



Effectively, VicRoads could complete three separate jobs using one set of Hawkeye 2000 data.

This is a great example of the data collected by ARRB's Hawkeye system being interrogated further to provide accurate road and non-road asset data

for state road authorities and local government areas.

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ARRB gives 800 students free helmets



Photos courtesy of Asia Injury Prevention Foundation

On the anniversary of the United Nations' Decade of Action for Road Safety launch, ARRB is sponsoring a helmet donation to 800 students and 28 teachers of Phnom Dil Primary School. The donation is part of a program called Helmets for Kids which is being implemented by the non-profit Asia Injury Prevention (AIP) Foundation. The program is supported by the National Road Safety Committee alongside other Cambodian ministries concerned with road safety.

Cambodian law currently does not require motorcycle passengers to wear helmets when they ride behind a driver, and this

leaves children particularly vulnerable to the road's dangers. In 2011 road traffic crashes lead to around 1,895 deaths and many of these victims were children.

Phnom Dil Primary School is located in Kampong Cham Province, along National Road 6. Proximity to this road creates a dangerous environment for the students because motorcycles, cars, buses, and trucks travel along the road at high frequency and speed. Virtually none of the children at this school wear helmets when they are driven to school.

The helmets were handed over to the

students at a ceremony attended by 200 people, including parents, local authorities, and partners. ARRB's sponsorship also includes extracurricular activities and communication with students' parents to reinforce their understanding of helmet use and encourage them to put helmets on their children.

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Conferences

13th AASHTO/TRB Maintenance Management Conference

Seattle, 14-19 July 2012

http://www.trb.org/Calendar/Blurbs/13th_AASHTOTRB_Maintenance_Management_Conference_164325.aspx

Australasian College of Road Safety National Conference: A Safe System - Expanding The Reach

Sydney, 9-10 August 2012

<http://www.acrs.org.au/activitiesandevents/>

2nd SARF/RTMC International Road Safety Conference 2012

Pretoria, 14-15 August 2012

http://www.irfnet.ch/eventdetail.php?catid=2&id=500&title=Second_SARF/RTMC_Road_Safety_Conference

2012 Australasian Roadmarking and Signs Conference: Driving Safely Into The Future

Hunter Valley NSW, 15-16 August 2012

<http://www.riaa.com.au/conference.html>

International Conference on Maintenance and Rehabilitation of Pavements and Technological Control

Auckland, 28-30 August 2012

<http://www.mairepav7.co.nz/>

4th European Pavement and Asset Management Conference

Malmö Sweden, 5-7 September 2012

http://www.vti.se/templates/Page_11329.aspx

International Conference on Long-Life Concrete Pavements

Seattle, 18 - 21 September 2012

<http://www.fhwa.dot.gov/pavement/concrete/2012conf.cfm>

7th Symposium on Pavement Surface Characteristics

Norfolk Virginia, 19-22 September 2012

http://www.trb.org/Calendar/Blurbs/7th_Symposium_on_Pavement_Surface_Characteristics_163620.aspx

Construction Materials Industry Conference: Essential Industry for Australia's Future

Melbourne, 19-22 September 2012

<http://www.iceaustralia.com/cm12/>

1st International Conference on Occupational Safety in Transport

Surfers Paradise, 20-21 September 2012

<http://ositconference.com/>



Photo: J. Best

Pavement asset research in the west

The Western Australian Pavement Asset Research Centre (WAPARC) is a collaboration between Main Roads Western Australia, ARRB Group, University of Western Australia, Curtin University of Technology and the Western Australian Local Government Association (WALGA).

Western Australia has an extensive road pavement network. The key challenges in managing this network are to provide for the increasing freight task and its impact on road pavements, the sustainable use of road making materials and maintaining pavement asset technical skills and capability.



WAPARC

WAPARC's purpose is to develop the knowledge and skills needed to reduce the whole-of-life costs of providing for pavement asset management in Western Australia, to improve road freight productivity and to provide a sustainable level of critical expertise supporting Main Roads, local government and industry.

As such it will deliver significant economic, environmental and social benefits. It addresses Western Australia issues and complements and extends the national research being undertaken by Austroads.

WAPARC's aim is to become a centre of excellence for pavement asset management in Western Australia.

Utilising cash and in-kind contributions of over \$3 million dollars over 3 years, WAPARC will initially address five key areas:

- Performance evaluation- developing a better understanding of pavement condition, behaviour and performance
- Economics of road networks – minimising whole-of-life costs
- Design of pavement structures – optimising pavement designs
- More sustainable pavements – researching more sustainable pavement alternatives
- Capacity/capability development – building a sustainable level of student, researcher and practitioner knowledge and expertise in pavement engineering and asset management.

The scope of the initial research projects addresses Main Roads short term needs and will enable evaluation of the research partnership model, with a review initiated 24 months into the initial 36 month period.

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Photo: iStockphoto

New Directors

At the ARRB Annual General Meeting in April, four Directors were elected to join ARRB's Board.

- Mr Peter Duncan (Chief Executive, Roads and Maritime Services, NSW)
- Mr Garry Liddle (Chief Executive, VicRoads – re-elected)
- Dr Kevin Thompson (immediate past Chief Executive Officer of Opus)

- Ms Ann Turner (Chief Executive Officer, Ann Turner Consultants).

Mr Don Larkin (Chair), Dr Matthew Cuthbertson and Mr Gerard Waldron (Managing Director) continue as Directors.

The re-elected, new and on-going Directors bring a wealth and diversity of experience to our Board which will be of great benefit to ARRB in the coming years.



Left to right: Mr Gary Liddle, Mr Peter Duncan, Ms Ann Turner, Dr Kevin Thompson.

ARRB delivers road safety audit training in Manila

ARRB's on-going commitment to international capacity building and knowledge transfer activities has recently been showcased via the first in a series of road safety audit (RSA) training courses delivered by John Hughes (Principal Advisor, Research and Consulting) at the Asian Development Bank (ADB) headquarters in Manila.

In line with the Decade of Action in Road Safety (DoA) 2011-2020, the Asian Development Bank has developed an Action Plan focussing attention on road safety in ADB's operations. This Action Plan includes the systematic training of ADB staff on road safety, preparation of road safety guidelines to incorporate road safety into the ADB project cycle, and mainstreaming this in the preparation of road safety investment. As part of this training, road safety auditing has been identified as one of the most effective tools to improve road safety and has sufficient versatility to permit it to be conducted at every stage of the lifecycle of the road.

The RSA training program delivered by ARRB is designed to assist, train and equip ADB staff to have a good overall understanding of RSA fundamentals, costs and benefits, procedures and implementation arrangements. These are important skills to enable RSAs to

be properly incorporated into the ADB project cycle. The course comprises both classroom and field-based components, allowing participants to grasp the technical material, and then apply it in a practical scenario. The first course was very well received, with many of the participants providing excellent feedback regarding their own learning outcomes, and knowledge which they can directly apply to addressing road safety concerns in each of their professions.

Initiatives such as this aim to build capacity with the overall goal of delivering widespread health and economic benefits. Road traffic crashes account for an estimated 1.27 million deaths and 50 million injuries worldwide each year with over 90% of reported deaths occurring in low and middle-income countries. Providing technical and management staff with the appropriate skills and expertise to manage road safety is a robust method of delivering measurable benefits and helping to reduce both the incidence and impact of road traffic crashes.

ARRB is well placed to deliver this training, given the wealth of experience and expertise in the preparation of best practice guides and manuals on road safety, road design and traffic management, and associated course



material. ARRB is officially a Registered Training Organisation (RTO) in partnership with the University of Ballarat, Australia. ARRB has a comprehensive knowledge transfer program that organises and delivers more than 80 workshops, seminars and forums each year, with more than 2,000 participants attending within Australia, New Zealand and overseas.

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Australian-first trial on Midland Highway

A by-product of paper manufacturing has been used in roadworks on the Midland Highway, in an Australian-first trial.

A small percentage of the by-product, sourced from processed plantation pine trees, was added to conventional bitumen during reseal works on the Midland Highway.

The trial is being led by ARRB on behalf of Austroads in a bid to extend the availability of bitumen.

Austroads Project Manager Lance Midgely said while bitumen is an important component needed for road construction in Australia, the future supply of bitumen may become limited or its cost may escalate significantly.

'Since bitumen can only be effectively manufactured from certain types of crude oils, future bitumen supply and cost will be directly linked to the worldwide availability of these suitable crude oils,' he said.

'The product we are trialling is relatively cheap and initial testing by ARRB has shown that it is safe to handle and has no detrimental effect on the properties of the conventional bitumen.'

VicRoads Regional Director Ewen Nevett said the trial is an important development in the evolution of road construction and maintenance practices in Australia and New Zealand.

'The successful incorporation of this waste by-product into bitumen has the

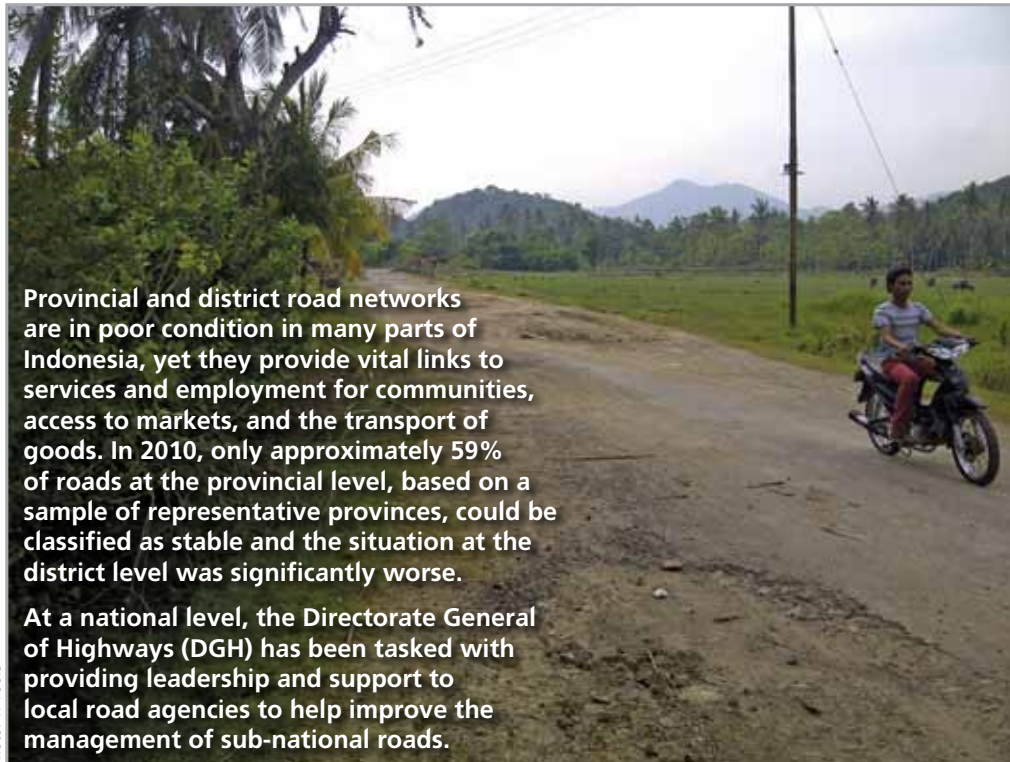
potential to partly replace or extend bitumen, which is a finite resource,' he said.

'VicRoads and ARRB will monitor the performance of the road surfacing over the next 12 months.

Should this trial be successful, other road authorities across the country will be encouraged to incorporate this practice into their road construction and maintenance works.'

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Improving road maintenance in Indonesia



In regard to the practical implementation of road maintenance, there are significant constraints affecting performance, but there are some positive signs and clear opportunities for corrective action. Operational efficiencies could be improved by implementing the alternative implementation models recommended in the study reports, in parallel with improvements to the existing modalities. Particularly with regard to output-focused maintenance, this being the recommended approach for both in-house units and contractors, experience and capability will be crucial, and can only be expected to be developed over time.

Achieving significant progress will require the issues of funding and capacity to be addressed within regional government road agencies. A challenge is to both

help establish a sustainable maintenance culture and address the backlog of major works, which is currently some 2.3 times the annual budget estimate for 2011/13.

A number of recommendations have been made on funding options for the future and these are now under consideration by the DGH and funding agencies including AusAid.

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For further information on the Indonesian Infrastructure Initiative visit www.indii.co.id

Provincial and district road networks are in poor condition in many parts of Indonesia, yet they provide vital links to services and employment for communities, access to markets, and the transport of goods. In 2010, only approximately 59% of roads at the provincial level, based on a sample of representative provinces, could be classified as stable and the situation at the district level was significantly worse.

At a national level, the Directorate General of Highways (DGH) has been tasked with providing leadership and support to local road agencies to help improve the management of sub-national roads.

In 2010 ARRB was engaged to lead a project to review current road maintenance practices and funding at the sub-national level to assist DGH in its mission. During Phase 1 of the study, team members, together with senior personnel from DGH, the Indonesia Infrastructure Initiative*, and specialists in the field, engaged in extensive consultations with selected road agencies representative of both eastern and western Indonesia. The team also sourced data on road conditions and funding, and undertook reviews of national and international practices.

From the work undertaken, it became clear that road maintenance at the subnational level in Indonesia is significantly under-resourced. Conditions have noticeably

deteriorated since decentralisation, and the responsible agencies have limited ability to objectively identify road maintenance needs, and to plan and then program the necessary works. Both routine and periodic maintenance have received insufficient financial backing, largely due to a lack of political support and visibility.

Phase 2 of the project was aimed at improving the efficiency and effectiveness of local government road maintenance planning, programming and budgeting, and led to the preparation of a draft *Road Maintenance Policy Statement and Technical Guidelines* and a draft *Road Maintenance Planning Procedures Manual*.

A survey of over 2000 km of roads and approximately 20% of provincial bridges was performed in the province of West Nusa Tenggara as a basis for confirming investment needs and for producing an initial work program to be applied in a pilot demonstration project. The findings for provincial roads were:

- 50% of the network was in good or fair condition, with significant disparities
- In Lombok 64% was serviceable compared with only 10% in Sumbawa.

*The Indonesia Infrastructure Initiative is funded by Australian aid and is managed by SMEC on behalf of AusAid.



Photo: T. Toole



Photo: T. Toole

TMR Metropolitan Region's network analysed

The Metropolitan Region of the Department of Transport and Main Roads (TMR) in Queensland is tasked with the preservation of the Other State Controlled Network (OSCR) (approximately 765 carriageway-km) to ensure road life is optimised, road performance is improved and safe, and relatively smooth roads are provided for all road users.

The Region has been asked to demonstrate its funding requirements in a defensible manner, optimise existing funding (in this context optimisation is about finding the best way to select rehabilitation and reseal projects to achieve an objective, such as the best network pavement condition, subject to budget restrictions) and estimate the funding required to maintain the asset to desirable levels of service.

This project informed the Region on:

- the impact of the current funding level and other budgets on the network
- an appropriate funding level to maintain the road pavement asset
- how existing funding can be optimised
- a pavement management strategy, including delivery of a 5-year works program
- the level of service being purchased for the funding level proposed.

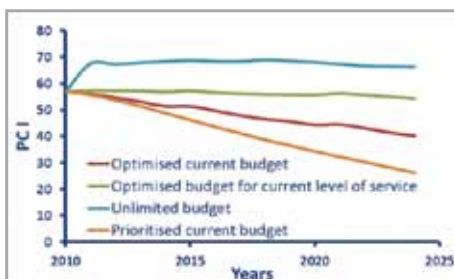
Working to Metro Region's requirements, ARRB has analysed the OSCR network using the decision support tool Deighton Total Infrastructure Management System (dTIMS) and adapted versions of the HDM-4 road deterioration and works

effects models, calibrated to south-east Queensland conditions. Data was sourced from TMR's ARMIS database, and surveys of deflections and ground penetrating radar were provided by the Region.

Representative values of the adjusted structural number (SNP) for a selection of nominal strength indicators and the design strength were calculated. The deflection data and pavement structure data were used to estimate the structural life of the pavements.

In addition to the HDM-4 models, a structural capacity model incorporating overlay design concepts and a risk module based on TMR's risk models were implemented.

A pavement condition index (PCI) was also implemented and the overall network condition was calculated by aggregating individual performance indicators. A scale from 0 to 100 was used, with 100 being the best.



The analysis investigated three budgets, namely, the existing funding, unconstrained funding and optimal funding. The scenarios included the base



Photo: L. Steele

case, ideal funding, current budget, alternative budgets and a prioritised budget to compare with the optimised budgets. Findings concerning the adequacy of the current funding and a recommended sustainable funding level were derived from the analysis. The results also demonstrated the effectiveness of optimisation when compared to prioritisation.

The structural evaluation highlighted the potential consequences of not distinguishing the weak and smooth from the strong and rough pavements, causing under or over-spending. Structural evaluation is essential for reliable long term performance and budget forecasts.

The risk assessment method developed by TMR was successfully implemented and used to influence project selection.

The involvement of ARRB in assisting the Metropolitan Region in optimising its current and future budgets has the potential to significantly improve the outcomes of the Region's road asset preservation program.

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Want to know what that means?

Check it out in the Austroads Glossary.

The Austroads Glossary includes definitions of thousands of terms covering pavement and materials technology, bridge technology, asset management, heavy vehicle operation, road safety, traffic engineering, and transport planning and economics. It also includes a list of organisational acronyms.

The current addition includes hundreds of new and revised terms which have

been added in response to user feedback and to take account of the many recent Austroads Guides and reports.

The Glossary is available from the Austroads website: www.austroads.com.au. Comments and suggestions are welcome. Please email:

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A method of determining depreciation of fine and coarse aggregate pavement that uses the high level of concrete heavy traffic loadings concrete itself, or a thin asphalt

ARRB Journal turns 50

The June edition marks the fiftieth anniversary of the first issue of Australian Road Research, the progenitor of **Road and Transport Research**. Since March 1962, the 'ARRB Journal', as it continues to be popularly known, has maintained quarterly reporting of research-related papers and events for transport practitioners and academics in Australia and New Zealand. Over these 50 years, about 1385 refereed papers have been published in the Journal over a wide range of road and transport-related topics.

The June 2012 issue contains papers on:

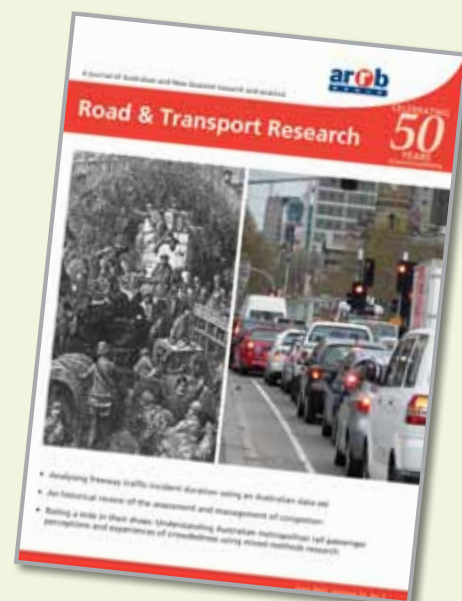
- Analysing freeway traffic-incident

duration using an Australian data set

- An historical review of the assessment and management of congestion
- Riding a mile in their shoes: Understanding Australian metropolitan rail passenger perceptions and experiences of crowdedness using mixed-methods research.

Shorter news items and upcoming conferences are also featured. Abstracts of past issues and other information can be viewed at www.arrb.com.au.

Subscription enquiries should be directed to info@arrb.com.au



New staff



Hanford Cheung has joined the Brisbane office as a Senior Engineer – Safe Systems. Hanford is a senior civil engineer specialised in traffic/transportation engineering with in-depth experience

in a wide range of civil and traffic engineering activities such as contract documentation/administration, traffic engineering, crash reduction studies, ITS and barrier technologies. He was recently Network Performance Manager for the Auckland Motorway Alliance. Hanford has a BEng(Civil) and MEngStudies (Transportation) from University of Auckland.



Erik Denneman has joined ARRB in the role of Principal Asphalt Engineer in the Bituminous Surfacing Group. Erik has worked in the Netherlands, USA and most recently in South Africa (where

he was Principal Researcher specialising in road surfacing materials in CSIR). Erik has a BEng(Civil) from Haarlem University, an MSc(Tech Man't) from Eindhoven University, a BEng(Transp Eng) and a PhD(Eng) from University of Pretoria.



Francis Lin has joined ARRB in Brisbane as a Graduate Engineer. Francis has a BEng(Civil/Environmental) and a MEngStudies (Transportation) from the University of Auckland.



Bao Nguyen has commenced in the Systems Division in the role of Customer Service Technician.

Bao has 10 years experience in the electrical and electronics

manufacturing industry and skills in designing, manufacturing, testing and calibration. Bao has a BEng(Electrical and Electronics) from the University of South Australia.



Shane Piper has also joined the Systems Division in Melbourne as the Operations/Project Manager. He will oversee project management, quality and customer support across the Division.

Shane's most recent roles included production and quality management. He has a BAppSci(Chemistry) and a post-graduate DipBusMant.



Anthony Rooke is a Principal Structural Engineer in the Brisbane office. Anthony's specialisations include structural asset management, asset management systems development,

civil structures design, bridge rating and overweight permit support. Anthony has spent the last 7 years in New Zealand involved in the management and delivery of structures asset management services to numerous clients including the New Zealand Transport Agency (NZTA) and local government.

One of Anthony's key achievements were managing initial response and subsequent recovery efforts for state highway structures following the Darfield and Christchurch earthquakes. He has a BEng (Civil and Structural Engineering).



Joshua Seskis has joined ARRB's Brisbane office as a graduate engineer. Joshua has an Advanced Diploma in Engineering Design (Structural) and a BEng(Civil and Infrastructures) from the RMIT University.

Knowledge transfer program 2012

The Knowledge Transfer group is continuing to provide the roads and traffic industry with a variety of different workshop topics to ensure training needs are catered for. The webinar program has also been implemented to help reach audiences far and wide. If you believe there is demand for a particular workshop or webinar topic that has not been scheduled, why not let us know? Email training@arrb.com.au

New South Wales

- Intersection and roundabout design, 10-12 July, Sydney (SOLD OUT)
- Managing road pavement assets, 17-18 July, Sydney
- Fundamentals of transport and accessibility modelling, 15-16 August, Sydney
- Parking design and management, 20-21 August, Sydney
- Local area traffic management, 21-22 August, Sydney
- Fundamentals of geotechnical investigation and design, 4 September, Sydney
- Treatment of crash locations, late 2012, Sydney, Tamworth, Parkes, Ballina, Newcastle, Penrith, and Wollongong

Victoria

- Freight & heavy vehicles: access & safety, 3-4 July, Melbourne
- Traffic theory and analysis, 11-12 July, Melbourne
- Managing road pavement assets, 14-15 August, Melbourne
- Intersection and roundabout design, 4-6 September, Melbourne
- Fundamentals of geotechnical investigation and design, 30 October, Melbourne
- Intersection & roundabout design, 11-13 December, Melbourne

Queensland

- Freight and heavy vehicles: access and safety, 17-18 July, Brisbane
- Intersection and roundabout design, 24-26 July, Brisbane (SOLD OUT)
- Treatment of crash locations, 30-31 August, Brisbane
- Traffic theory and analysis, 5-6

September, Brisbane

- Fundamentals of geotechnical investigation and design, 16 October, Brisbane
- Level 1 bridge inspection, 23-24 October, Brisbane
- Level 2 bridge inspection, 25-26 October, Brisbane

Western Australia

- Treatment of crash locations, 18-19 July, Perth
- Intersection & roundabout design, 7-9 August, Perth (SOLD OUT)
- Freight and heavy vehicles: access and safety, 28-29 August, Perth
- Parking design and management, 12-13 September, Perth
- Intersection and roundabout design, 23-25 October, Perth
- Mining roads: a systematic approach to safety and traffic management, 7-8 November, Perth
- Fundamentals of geotechnical investigation and design, 13 November, Perth

South Australia

- Treatment of crash locations, 26-27 July, Adelaide
- Traffic theory and analysis, 1-2 August, Adelaide
- Intersection and roundabout design, 14-16 August, Adelaide
- Parking design and management, 3-4 October, Adelaide
- Freight and heavy vehicles: access and safety, 23-24 October, Adelaide

Tasmania

- Intersection and roundabout design, 28-30 August, Hobart

Australian Capital Territory

- Treatment of crash locations, 7-8 August, Canberra
- Intersection and roundabout design, 13-15 November, Canberra

Northern Territory

- Treatment of crash locations, 27-28 August, Darwin
- Intersection and roundabout design, 20-22 November, Darwin

New Zealand

- Intersection and roundabout design, 27-29 November, Auckland

Freight & heavy vehicles: access & safety: Will provide delegates with a thorough understanding of heavy vehicle dynamics topics related to safety and infrastructure performance, and related themes including the Performance Based Standards (PBS) accreditation scheme, and the innovative route assessment and network classification approach.

Fundamentals of geotechnical investigation & design: Will be based on the background material supporting the *Austroads Guide to Road Design Part 7: Geotechnical Investigation and Design*. It will cover material relating to best practice techniques, methods of field investigation, laboratory tests, geotechnical reports, potential risks and geotechnical information normally required for each design element.

Fundamentals of transport and accessibility modelling: Topics will include generation and attraction models, origin-destination (OD) models, mode choice models, and network assignment techniques. Delegates will be instructed on the use of spreadsheets and programs such as the Furness algorithm for OD models and maximum likelihood estimation for the calibration of mode choice models. The ARRBS Traffic Assignment Program (which is an incremental assignment and user-equilibrium assignment program) will be provided. Participants will also learn the fundamentals of accessibility measurement, including the ARRBS Accessibility Metric and the use of transport models for assessing accessibility at a city and neighbourhood level.

Intersection & roundabout design: Two complementary workshops will be based on the *Austroads Guide to Road Design*. The Intersections at Grade workshop will cover *GRD Part 4A: Unsignalised and Signalised Intersections*, while the Roundabouts workshop will be based on *GRD Part 4B: Roundabouts*. These workshops cover traffic management issues and geometric design considerations at intersections and roundabouts. Attend either or both.

(continued next page)

Knowledge transfer program 2012

Level 1 bridge inspection: For those involved with the routine maintenance inspection of bridge structures and culverts. Participants will develop skills to conduct Level 1 inspections and complete the Level 1 inspection report form, on which to base the required maintenance intervention. Also the workshop will enable delegates to recognise and assess bridge condition problems essential for Level 2 inspections.

Level 2 bridge inspection: For those involved with the inspection of bridges and culverts. A Level 2 inspection involves the identification of every bridge component and the rating of the condition of that component. This can be used to generate an overall score or rating for the bridge for the prioritisation



Photo: M. Farrinden

of repairs, major maintenance, rehabilitation and/or replacement. Participants will develop skills to conduct Level 2 inspections and will be given information on safety awareness around structures, special access equipment, and the recommended procedures. The Level 2 bridge inspection course is also nationally accredited.

Local area traffic management: Will be based on the *Austrroads Guide to Traffic Management Part 8: Local Area Traffic Management*. It will cover material relating to best practice techniques, available resources, design principles, device selection, special needs of different road users, legal issues and a

case study syndicate exercise to provide hands on experience applying the latest practice.

Managing road pavement assets: The first day will provide participants with an overview of the fundamentals of road pavement asset management, while the second day will outline in greater detail the tools now available to effectively identify, record and manage road pavement assets. The workshop will be delivered by ARRB's asset management specialists who have a wide range of experience from research, operations and private enterprise.

Mining roads: Provides participants with practical and applicable knowledge in the areas of road safety, traffic management and road asset management. Additionally, the workshop provides an introduction to the conduct of incident investigations and the importance of feeding back the lessons of any incidents into positive improvements in strategy, policy and practices.

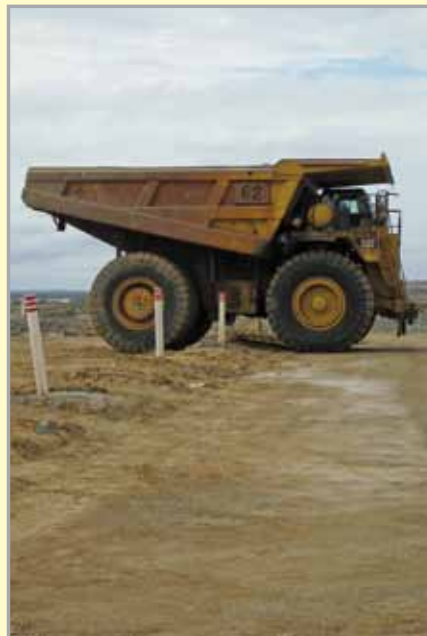


Photo: D. Vagaja

Parking design & management:

Based on the background material supporting the *Austrroads Guide to Traffic Management Part 11: Parking* supplemented with additional information drawn from Australian Standard AS2890.1-5. It will cover material relating to best practice techniques, available resources, design principles, on- and off-street requirements, special needs of different users, architectural and urban design considerations, and a case study syndicate exercise to provide hands-on experience applying the latest practice.

Traffic theory and analysis: Will present and explain the key areas of traffic theory, illustrate their application to various types of traffic analysis and provide participants with hands-on practice in identifying and undertaking the analyses appropriate to different situations.

Treatment of crash locations: Will outline the latest practices applying to the investigation and treatment of crash locations. The workshop will cover providing a Safe System, road safety engineering, human factors, police investigation, identifying crash locations, diagnosing the crash problem at the site, selecting an effective solution, crash costs, economic appraisal, monitoring and evaluations.

For further information:

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