



ENHANCING RESILIENCE OF CRITICAL ROAD INFRASTRUCTURE: BRIDGES, CULVERTS AND FLOOD-WAYS UNDER NATURAL HAZARDS

Annual project report 2015-2016

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Cover: Kapernicks bridge in the Lockyer Valley. Photo by Hessam Mohseni



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EXECUTIVE SUMMARY

In the funded first stage, the project aims to develop vulnerability models for critical road structures: bridges, culverts and floodways under natural hazards of flood, bush fire and earthquakes. In the second stage of the project, optimised maintenance and strengthening regimes required to enhance resilience of critical road structures will be identified and a decision making tool will be developed.

During the past year, the research focused on analysis of the case studies available from end user partners and development of the methodology for vulnerability modeling of bridges and floodways under natural hazards of flood, earthquake and bushfires. Three case studies were analysed to further establish the methodology and a reliability based approach was established to account for the variability of the frequency and the intensity of disasters. A field study was undertaken to understand the economic impact due to failure of road structures during the 2011 and 2013 floods in the Lockyer Valley region in Queensland.

Four workshops and a number of informal meetings were held during the project with excellent participation of end users and researchers. A mini-symposium held in July 2015 at RMIT University brought researchers, end users and wider stakeholders from across Australia and the UK. A stakeholder workshop held on 17 March 2016 identified end user needs and a utilisation plan was developed based on the outcomes. During the workshops, case study data were identified and the methodology for vulnerability modeling was refined. Future data needs were communicated to the end users.

Five Ph.D candidates commenced work with the research team on APA and IPRS scholarships. Three of the students secured Bushfire and Natural Hazards CRC's top up scholarships as well. One Masters by research student and one PhD will complete in 2016 and 2017 respectively. Each of the four strands of the project has recruited a researcher to engage in the project and also utilised final year undergraduate projects to contribute to the research project.

Major outcomes during the past two years can be summarised as development of the vulnerability modeling methodology for critical road structures exposed to extreme events and demonstration of the methodology using four case studies. This work has been published in 26 Publications including 9 journal papers, 12 refereed conference papers and 5 reports. In addition, the project research team has been invited to a total number of 12 highly regarded conferences roundtables, workshops and forums to present keynote speeches, chair and co-chair panels and facilitate workshops.



END USER STATEMENT

Leesa Carson

Branch Head, Community Safety Community Safety & Earth Monitoring Division
Geoscience Australia

Road networks play a key role in Australia's economy and resilience of communities. This project is filling an important gap in understanding the vulnerability of road infrastructure to natural hazards and the impact to communities.

The project is currently on track and has delivered its scheduled outputs. The focus of the work this year has been in analysing case studies from end users and further development of vulnerability model methodology for critical road infrastructure for flood, earthquake and bushfire.

The project has had another positive 12 months of stakeholder engagement, presenting reports to key stakeholders, informal meetings, and engagement with the community to understand their perspective. A positive outcome of the proactive engagement is reflected in the bridge engineers considering natural hazards and structural resilience in bridge construction and State road agencies requesting input into their road management processes.

Three interesting utilisation activities to transfer knowledge gained to practice have been developed as a result of a constructive end user workshop, which will inform the project end user engagement over the next 12 months.



INTRODUCTION

What is the problem?

Increasing frequency and intensity of natural hazards in Australia has led to scenarios where the infrastructure is subjected to loading regimes beyond those prescribed in the current design codes. Australia relies very heavily on its road network, which plays a vital part in the national economy as well as reducing the vulnerability of the community at large before, during and after extreme climate events [1]. Questions which require answers are: how does the road network - especially critical road structures such as bridges, culverts and floodways - cope with extreme natural hazards and how can the resilience of these be improved? This project aims to fill a major gap in critical road infrastructure research related to risk identification, assessment and monitoring using an integrated multi-hazard approach.

Why is it important?

In recent years there has been significant damage to road networks throughout Australia from floods and bushfires that have cost both State and Federal governments millions of dollars to repair. The effect of damage to road networks from natural hazards goes far beyond the immediate damage incurred by people whose homes and businesses are directly affected, and if the damage is widespread it can have an impact on the regional and national economy. The cost of repairing the road network alone is huge. For instance, the 2010-2011 floods in Queensland severely damaged 9,170 kilometres of road network including bridges, flood ways and culverts and cost the State and Federal government hundreds of millions of dollars to repair [1]. In Victoria, VicRoads spent over \$17 million on repairing the road network after the bushfires in 2009 and over \$200 million repairing the road network after the 2011 flood [2]. Creating a road network that can better withstand future natural hazards and better understanding of the impact on community will be of great importance in reducing the cost to the community and road authorities as well as local councils.

How are we going to solve it?

This project will take a hardening mode approach and for critical road structures this requires consideration of three aspects:

1. Vulnerability modeling of structures under extreme events, considering the design loads, standards and recently observed variability in intensity and frequency of disasters
2. Methods of enhancing resilience of road structures using optimised maintenance and strengthening
3. Understanding the effect of vulnerability of road structures on the community resilience before, during and after an extreme event.



PROJECT BACKGROUND

Australia's variable climate has always been a factor in natural disasters that have had significant impact on an evolving road infrastructure and on the communities that rely on the roads. The following figure (Fig. 1) shows the average annual cost of natural disasters by state and territory between 1967 and 2005.

State and territory	Flood	Severe storms	Cyclones	Earthquakes	Bushfires	Total
	Cost (\$ million in 2005 Australian dollars) ^a					
NSW	172.3	217.1	0.6	145.7	23.9	559.6
VIC	40.2	23.8	0.0	0.0	36.7	100.6
QLD	124.5	46.7	99.3	0.0	0.7	271.2
SA	19.3	16.7	0.0	0.0	13.0	49.0
WA	4.7	13.0	43.3	3.1	4.6	68.7
TAS	6.9	1.2	0.0	0.0	11.5	19.5
NT	9.1	0.4	138.5	0.3	0.0	148.3
ACT	0.0	0.5	0.0	0.0	9.7	10.2
Australia	376.9	325.2^b	281.6	149.1	100.1	1232.9
Share of total (per cent) ^c	30.9	26.7	23.1	12.2	8.2	100.0

a. These figures exclude the cost of death and injury.

b. Figure includes costs associated with a storm involving several eastern states (\$216.7 million) which has not been allocated to any individual state data in the table.

c. Figures may not add to totals due to rounding.

Source: BITRE analysis of Emergency Management Australia database <www.ema.gov.au>.

FIGURE 1: AVERAGE ANNUAL COST OF NATURAL DISASTERS BY STATE AND TERRITORY, 1967-2005 (BITRE, 2008:44)

From these data it can be seen that during this period severe storms and cyclones inflicted the most economic damage, followed by flooding. The data are strongly influenced by three extreme events - Cyclone Tracy in NT (1974), the Newcastle earthquake in NSW (1989) and the Sydney hailstorm also NSW (1999), as well as three flood events in Queensland (South East Qld, 2001; Western Qld, 2004; and the Sunshine Coast, 2005). Climate change has increased the risk from extreme events and the update of this table that includes data for the years 2007 to 2013 - during which there were extreme climate events in Qld, Vic, SA and NSW.

The recent flood events in Queensland, Australia had an adverse effect on the country's social and economic growth. Queensland state controlled road network include 33,337 km of roads and 6,500 bridges and culverts [3]. 2011-2012 flood in Queensland produced record flood levels in southwest Queensland and above average rainfall over the rest of the state [4]. Frequency of flood events in Queensland, during the past decade appears to have increased. In 2009 March flood in North West Queensland covered 62% of the state with water costing \$234 million damage to infrastructure [5]. Theodore in Queensland was flooded three times within 12 months in 2010 and it was the first town, which had to be completely evacuated in Queensland. 2010-2011 floods in Queensland had a huge impact particularly on central and southern Queensland resulting in the state owned properties such as 9,170 road network, 4,748 rail network, 89



severely damaged bridges and culverts, 411 schools and 138 national parks [6]. Approximately 18,000 residential and commercial properties were significantly affected in Brisbane and Ipswich [7] during this time. More than \$42 million support was provided to individual, families and households while more than \$121 million in grants have been provided to small businesses, primary producers and not-for-profit organisations. Furthermore, more than \$12 million in concessional loans to small businesses and primary producers have been provided (Rebuilding a stronger, more resilient Queensland, 2012). The Australian and Queensland governments have committed \$6.8 billion to rebuilding the state.

Pritchard [4] identifies that urban debris, such as cars, and the insufficient bridge span for debris to pass through are main causes for damaging bridges in the aftermath of 2011/2012 flood in Queensland. Using the 2013 flood event in Lockyer Valley, Lokuge and Setunge [8] concluded that it is necessary to investigate the failure patterns and the construction practices adopted during the initial construction and rehabilitation stages in the lifetime of bridges. These findings raised a question that what are the failure mechanisms and contributing factors which requires consideration in designing of bridges to be resilient to extreme flood events.

THE PROJECT

Multi-hazard vulnerability modelling at a detailed level, which aids managing authorities of road structures to prioritise hardening of structures, considering the intensity of disasters, vulnerability of structures and the impact on community resilience is not available to date. The project aims to deliver following outcomes over the first stage of 3.5 years currently funded by the Bushfire and Natural Hazards CRC:

- Advancement in understanding input hazard parameters for quantifying impact of hazards on road structures
- Understanding failure mechanisms under different hazard types and vulnerable structural forms – clustering of structural forms according to vulnerability
- Quantifying community impact of failure of critical road structures
- Multi hazard vulnerability profile for road structures in case study regions

Multi hazards included are flood, earthquake, bush fire and climate change. In the second stage of the project, the derived vulnerability models for the two case study regions will be used to develop a tool which can be used for vulnerability modelling of any given region in Australia. This will be further developed as a GIS based software tool. Thus the outcomes of the second stage will be:

- GIS based software tool for vulnerability modelling of road structures for a given region with required input parameters
- Road infrastructure retrofitting options and optimisation strategies
- Generic framework for vulnerability assessment of infrastructure



To achieve the above outcomes, the following approach will be adopted by the researchers:

1. Stage 1: Vulnerability Modeling
 - a) Analysis of case studies of failure – Lockyer Valley and critical regions in Victoria
 - b) Input exposure parameters for multi hazard analysis will be sourced
 - c) Critical failure mechanisms and modes will be established
 - d) Community Impact of failure of road structures will be quantified
 - e) Australian design standards for road structures will be examined and gaps in design practice will be identified
 - f) A methodology for vulnerability modeling of road network to understand the risk of failure of road structures will be developed.
2. Stage 2: Prototype tool for vulnerability of road structures and optimised strengthening
 - a) Develop a GIS tool to map vulnerability
 - b) Calibrate the vulnerability models with two other case study areas
 - c) Identify strengthening methods
 - d) Deliver a methodology and a tool for optimised strengthening of structures



PROGRESS TO DATE

RESEARCH ACTIVITIES

During the past year the research methodology has been further refined and presented to the end users. Specific activities associated with this are summarised below:

1. Failure mechanisms of road structures under three disaster events: Flood, Bush Fire and Earthquakes have been completed. The CRC report no.3: "Failure mechanisms of bridge structures under natural hazards" has been completed and refined with end user feedback.
2. Vulnerability modelling has been completed for the hazards of Flood, Bush Fire and Earthquakes with two case studies of bridges and one case study of floodway failure completed.
3. Australian design standards for bridges and floodways have been examined and a comparative study of international standards have been undertaken to ensure that we are using the best available knowledge in vulnerability modelling.
4. Report 4 on "Analysis of design standards and applied loads on road structures under extreme events" has been completed. Reviews have been received from end users and the report has been finalised.
5. A reliability based approach to include variability of disaster frequency and intensity in to vulnerability modelling has been developed.
6. Three utilisation activities are proposed to transfer knowledge gained from the project to practice. These were guided by the significant end user engagement activities which happened during the year.
7. A framework for calculating the economic impact of failure of road structures has been developed.
8. In the last year, the project generated 21 publications: 7 journal papers, 11 conference papers and 3 reports; which bring the total number of publications of the project to 25. We have three more publications under review.

WORKSHOPS OF RESEARCHERS AND END USERS

During the past year, following end user engagement activities were completed:

1. A mini-symposium was held on 13th July at RMIT in Melbourne where researchers, end-users and wider stakeholders from across Australia and the UK presented and discussed the work. Feedback from CEO of the CRC: Dr. Thornton, end-users, other researchers and wider stakeholders were captured and used to guide the research activities.
2. A presentation was made to the Austroads committee on 21 October 2015 to disseminate the findings and secure Austroads support to provide a pathway for translation of knowledge.
3. 4th End-user workshop held at the University of Southern Queensland on 7th March 2016 with 35 attendees (23 end-user and industry reps., Bushfire and Natural Hazards CRC Research Manager, 7 researchers & 4 students).



4. A number of other informal events were held: meeting with Queensland Main Roads on 30/Oct/2014 & 26/Mar/2015, VicRoads on 19/Nov/2015 And RMS on 31/Jul/2015

RECRUITING DURING THE PAST YEAR

- Ms. Zeinab Yazdanfar (PhD candidate, APA Scholarship)
- Mr. Ismail Qeshta (Ph.D Candidate, IPRS scholarship)

MAJOR EQUIPMENT PURCHASES

- No major equipment purchases

MAJOR FIELD TRIPS

Case study 2: Consequence assessment LVRC

16 November 2015

Impact assessment on road structures were conducted in the Lockyer Valley on 16 November 2015 by RMIT researchers Hessam Mohseni and Albert Zhang. Following the field inspection a meeting was held with a Lockyer Valley Regional Council representative to clarify and validate the findings.

CONFERENCES ATTENDED REPRESENTING THE BUSHFIRE AND NATURAL HAZARDS CRC

1. International Conference on Bridge Maintenance, Safety and Management (IABMAS), 2016
2. 6th International Conference on Building Resilience, 2016
3. 5th International Conference on Building Resilience, 2015
4. AFAC Conference, September 2015
5. VicRoads Structures Conference, 2015
6. Safeguarding Australia - Blast and other extreme events -Design and Modelling Forum, May 2015
7. International Conference on Structural Engineering and Construction Management, December, 2015
8. 10th Annual RMS Bridge Conference, 'Bridges – Safe and Effective Road Network', December 2015



PUBLICATION LIST

Journal papers

- Published journal papers (SJR ranking)
 - WAHALATHANTRI, B.L., LOKUGE, W., KARUNASENA, W. & SETUNGE, S. (2015) Vulnerability of floodways under extreme flood events. *Natural Hazards Review*, American Society of Civil Engineers-ASCE, 2016, 17 (1), doi:10.1061/(ASCE)NH.1527-6996.0000194, ISSN 1527-6988. **(Q1)**
- Journal papers accepted for publication
 - LOKUGE, W., GAMAGE, N. & SETUNGE, S. Fault tree analysis method for deterioration of timber bridges using an Australian case study, *Built Environment Project and Asset Management*, Emerald Group of Publishing (accepted for publication on the 23 March 2016) **(Q3)**
 - KAFLE, B., ZHANG, L., MENDIS, P., HERATH, N., MAIZUAR, M., DUFFIELD, C., THOMPSON, R., 2015 Monitoring the dynamic behaviour of the Merlynston creek bridge using interferometric radar sensors and finite element modelling, *International Journal of applied mechanics* (Accepted on 04-05-2016), **(Q2)**
- Submitted journal papers
 - PATHIRANAGE, T. & LOKUGE, W. Vulnerability assessment of bridges subjected to extreme cyclonic events, *Natural Hazards*, Springer (Submitted) **(Q1)**
 - HERATH, N., MENDIS, P., NGO, T., SETUNGE, S. & MOHSENI, H. (2015), Vulnerability assessment of a typical girder bridge in Australia due to seismic loads, *Journal of Disaster Risk Studies* (Submitted) **(Q4)**
 - McEvoy, D., Mullett, J., Mohseni, H., & Setunge, S. (2016), Community resilience to flooding and road network disruption in Australia: a local construction of socio-ecological resilience, *Regional Environmental Change*, Springer (Submitted) **(Q2)**
 - Fraser, C., Lokuge, W. & Karunasena, W., Performance of bridges with damaged elements in extreme flood events, *Structure and Infrastructure Engineering*, Taylor & Francis (Submitted) **(Q1)**

Conference papers

- Conference papers presented
 - SETUNGE S., LOKUGE, W., MOHSENI, H. & KARUNASENA, W. 2014. Vulnerability of road bridge infrastructure: Under extreme flood events. AFAC and Bushfire & Natural Hazards CRC Conference 2014
 - WAHALATHANTRI, B.L., LOKUGE, W., KARUNASENA, W. & SETUNGE, S. 2015. Framework to inspect floodways towards estimating damage. AFAC and Bushfire & Natural Hazards CRC Conference 2015
 - FRASER, C., LOKUGE, W. & KARUNASENA, W. 2016. Vulnerability of bridges in extreme flood events based on element failure. AFAC



- and Bushfire & Natural Hazards CRC Conference 2016 (accepted for poster presentation)
- LOKUGE, W., MOHSENI, H., SETUNGE, S. & Simpson, S. 2015. Evaluation of a case study concrete bridge in Victoria under effect of bushfire. Proceedings of the 5th International Conference on Building Resilience pp 477-481.
 - WAHALATHANTRI, B. L., LOKUGE, W., KARUNASENA, W. & SETUNGE, S. 2015. Emergency service demand in Queensland during natural disasters. Proceedings of the 5th International Conference on Building Resilience pp 473-476.
 - KALENDER, F., SETUNGE, S., MOHSENI, H. AND LOKUGE, W. "Deriving damage indices for concrete girder bridges subjected to flood loading", 6th International Conference on Structural Engineering and Construction Management, 11-13 Dec 2015, Kandy, Sri Lanka, pp: 29 – 35
 - HAYAT, E., AMARATUNGA, D. & MALALGODA, C. (2015), THE CHALLENGES AND OBSTACLES OF POST-DISASTER ROAD INFRASTRUCTURE RECONSTRUCTION, Proceedings of the 6th International Conference on Structural Engineering and Construction Management (ICSECM). 12-13 December 2015. University of Peradeniya. Sri Lanka. ISBN: 978-955-589-210-0
 - Haigh, R. & Amaratunga, D. (2015). Moving from 2015 to 2030: challenges and opportunities for higher education in developing resilience to disasters, Proceedings of the 8th Faculty of Architecture Research Unit (FARU) International Conference on "making Built Environment responsive", 11-12 December 2015, University of Moratuwa. Sri Lanka. ISBN: 978-955-9027-53-9
 - Conference papers accepted
 - MOHSENI, H., SETUNGE, S. & TRAN H. D. 2016, Optimisation and prioritisation of bridge inspection and maintenance activities – 8th International Conference on Bridge Maintenance, Safety and Management (IABMAS 2016)
 - KALENDER, M.F., SETUNGE, S. & MOHSENI, H. 2016, Analysis of flood impact on reinforced concrete girder bridges – a case study, 8th International Conference on Bridge Maintenance, Safety and Management (IABMAS 2016)
 - GAJANAYAKE, A., MOHSENI, H., ZHANG, G. & SETUNGE, S. (2016). Measuring social, environmental and economic Impacts of road structure failure. Proceedings of the 6th International Conference on Building Resilience

Bushfire and Natural Hazards CRC Reports

- Report 4, 2016: Analysis of design standards and applied loads on road structures under extreme events. Bushfire and natural hazards cooperative research centre Bushfire and Natural Hazards CRC
- Report 3, 2015. Failure mechanisms of bridge structures under natural hazards Bushfire and natural hazards cooperative research centre Bushfire and Natural Hazards CRC



Invited presentations

1. Prof Setunge and A/Prof Zhang presented key papers at the 4th International Conference on Building Resilience Incorporating the 3rd Annual Conference of the ANDROID Disaster Resilience Network 2014, Manchester, 2014.
2. Prof Setunge presented a keynote speech entitled “Doing more with less in infrastructure asset management” at the Local Government (LG) Asset Management and Infrastructure National Conference on 14 May 2015, in Melbourne.
3. Dr. Mohseni presented the project’s research by invitation at the Safeguarding Australia 2015 (the 12th National Security Annual Summit)- Blast and other extreme events -Design and Modelling Forum for Practitioners and Researchers.
4. Dr. Mohseni presented an invited paper at the VicRoads Structures Conference – Strong Structures, Strong Economy (April 2015).
5. MOHSENI, H., SETUNGE, S. & MENDIS, P. 2015 Resilience assessment of Australian road structures due to natural hazards the 10th Annual RMS Bridge Conference.
6. Prof Priyan Mendis was invited to present on Earthquake Resistant Structures at 6th International Conference on Structural Engineering and Construction Management in December **2015**, Sri Lanka.
7. Prof Setunge was invited as a presenter for the workshop “Ensuring Accountability in Disaster Risk Management and Reconstruction” on 8 December 2015.
8. Prof Setunge participated in a workshop conducted by an EU funded project on “Collaborative Actions in Disaster Resilience Education” (CADRE) on the topic “Market Demands in the Construction Industry to Increase Societal Resilience to Disasters” on 9 December 2015.
9. Prof Amaratunga was invited for: Key note speech : “Developing a resilient built environment”. Sêr Cymru NRN-LCEE & Royal Society of Biology Workshop on Exploring Resilience, 18 May 2016, SSE Swalec, Cardiff. This event is organised by the Sêr Cymru National Research Network for Low Carbon, Energy and Environment (NRN-LCEE), in partnership with the Royal Society of Biology (RSB)
10. Prof Amaratunga was invited for: Key note speech, “Words Into Action” Guidelines for the Sendai Framework - Working Group on DRR Governance and Accountability, ISDR Inter Governmental Support Group, 26 January 2016, CICG, Geneva, Switzerland.
11. Prof Amaratunga delivered a key note lecture entitled: “Research and innovation to address societal challenges: Priorities for EU-South Asia cooperation in Horizon 2020”, at the 3rd PlanoCosmo and 10th SSMS International Conference on ‘Resilient City, Resilient Region’, held from 26 – 27 October 2015 at the Institute Technology of Bandung, Bandung, Indonesia. This international conference was jointly organised by Department of Urban and Regional Planning of Institute Technology of Bandung and the Society of Social Management System.
12. Prof Amaratunga was invited for: Invited speech, International best practices, Conventions, knowledge transfer mechanisms, The future we



- want; Safer Sri Lanka; Disaster Management Conference; 24-26 September, 2014 – BMICH, Colombo 07, Sri Lanka; To assess and share the lessons learned, best practices, repercussions, challenges of disaster risk management and development activities initiated by the DRM stakeholders in Sri Lanka since 2004 Great Indian Ocean Tsunami.
13. Prof Amaratunga was invited for: Panel Co-chair – Roundtable discussion on the role of Higher Education in supporting implementation of the Sendai Framework for Disaster Risk Reduction 2015-2030, 5th The international conference on building resilience, exploring the concept of resilience as a useful framework of analysis for how society can cope with the threat of natural and human induced hazards, Newcastle, Australia, 15th-17th July 2015
 14. Prof Amaratunga was invited for: Organiser Reducing Disaster Risk in Urban Settings - Intergovernmental Segment, Ministerial Roundtable, 16th March 2015, at Sendai International Centre, Japan as part of the UN World Conference on Disaster Risk Reduction.
 15. Prof Amaratunga was invited for: Organiser and facilitator - Local Governments Roundtable, The Sendai International Centre in Japan, Third United Nations World Conference on Disaster Reduction (WCDRR), March 2015.
 16. Prof Amaratunga was invited for: Multi-Stakeholder Segment, Working Session: “Applying Science and Technology to Disaster Risk Reduction Decision-Making” as a member of the Science and Technology Major group at the UN World Conference on Disaster Risk Reduction held in Sendai, Japan, March 2015. This session set the agenda for the future of science and research for disaster risk reduction and explore new partnerships for promoting evidence-based disaster risk reduction for sustainable development. The session also discussed the proposal of the scientific community to re-initiate an international scientific advisory mechanism for disaster risk.
 17. Prof Amaratunga was invited for: A key note address entitled “Tackling societal challenges through international collaboration” at the Disasters and Human Security Public Forum organised at the UN World Conference on Disaster Risk Reduction held in Sendai, Japan from 14 – 18 March 2015. Tohoku University International Program in Human Security and United Nations University Institute for Environment and Human Security jointly hosted this public forum.
 18. Prof Amaratunga was invited for: Panel co-lead, panel discussion on Disaster Resilience education, 10th International Conference of The International Institute for Infrastructure Resilience and Reconstruction (I3R2): Collaboration for Effective Disaster Mitigation and Response was held from May 20-22, 2014 Purdue University, Indiana, USA
 19. Prof Amaratunga was invited for: UNHABITAT World Urban Forum - Resilience Dialogue : Raising Standards of Urban Resilience Friday, 11 April 2014, Medellín, Columbia Agenda DRAFT_20 March_2014 (The primary aim of this Dialogue is to demonstrate how a holistic approach to urban resilience that considers all functions of an urban system can contribute to making all cities more equitable places to live and work)



20. Prof Amaratunga was invited for: UNHABITAT World Urban Forum
University round table: Universities addressing Urban challenges. 10 April
2014, Medellín, Columbia . Agenda DRAFT_20 March_2014 The
roundtable gathered scholars, experts, researchers, university
representatives and heads of thematic areas of UN- Habitat to discuss
the role of knowledge and education, as well as the possible
contributions of universities to address the challenges of sustainable
urbanisation in the 21st century.



LIST OF CURRENT INTEGRATED TEAM MEMBERS

Researchers	Research Students	End Users
Dr. Buddhi Wahalathantri	Mr. Albert Zhang	Dr. Ross Pritchard, Executive Director, structures, QTMR
Prof. Chun Qing Li	Mr. Amila Dissanayake	Leesa Carson, Branch Head, Community Safety, Geoscience Australia
Dr. Damith Mohotti	Mr. Farook Kalendher	Ralph Smith, Branch Manager, Environmental Protection Branch, Department of Fire & Emergency Services WA
Prof. Darryn McEvoy	Mr. Ismail Qeshta	Myles Fairbairn CEO, Lockyer Valley Regional Council
Prof. Dilanthi Amaratunga	Ms. Maryam Nasim	Mr. Nigel Powers, Manager, Operations, VicRoads
Dr. Hessam Mohseni	Ms. Zeinab Yazdanfar	
Dr. Jane Mullett		
Prof. Karu Karunasena		
A/Prof. Kevin Zhang		
Dr. Nilupa Herath		
Prof. Priyan Mendis		
Prof. Sujeeva Setunge		
Dr. Tuan Duc Ngo		
Dr. Weena Lokuge		



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2. in *Herald Sun*. 2011.
3. Kuhlicke, C., *Resilience: a capacity and a myth: findings from an in-depth case study in disaster management research*. Natural Hazards, 2010.
4. Pritchard, R.W., *2011 to 2012 Queensland floods and cyclone events: Lessons learnt for bridge transport infrastructure*. Australian Journal of Structural Engineering, 2013. **14**(2): p. 167-176.
5. *Increasing Queensland's resilience to inland flooding in a changing climate*. 2010 [cited 2012 20 April]; Available from: <http://www.ehp.qld.gov.au/climatechange/pdf/inland-flood-study.pdf>.
6. *Rebuilding a stronger, more resilient Queensland*. 2012 [cited 2013 22 April]; Available from: <http://www.qldreconstruction.org.au/u/lib/cms2/rebuilding-resilient-qld-full.pdf>.
7. *Queensland floods: The economic impact Special Report*. 2011 [cited 2013 April 2013]; Available from: <http://www.ibisworld.com.au/common/pdf/QLD%20floods%20special%20report.pdf>.
8. Lokuge, W. and S. Setunge, *Evaluating disaster resilience of bridge infrastructure when exposed to extreme natural events*, in *International conference on disaster resilience*. 2013: Sri Lanka.