Resilience of Distributed Transportation Infrastructure Workshop

Workshop Summary Report

December 2016

The University of Auckland

Contract Reference: E6567-UoA-Costello 16018

Date and Venue

The workshop was held on the 1st December 2016 at the Pullman Hotel in Auckland.

Attendance

Attendees included representatives from the University of Auckland, University of Canterbury, Massey University, National Infrastructure Unit, GNS Science, National Institute of Water and Atmospheric Research (NIWA), OPUS Research, AECOM, Tonkin+Taylor, Downer, EY and Market Economics. Representatives from asset owners included New Zealand Transport Agency, KiwiRail, Auckland Transport and Auckland Council – including JMAC, ATOC and Lifelines representatives. The full list of the 31 attendees is included as Appendix A.

Apologies were given by Stuart Woods (NZ Transport Agency) who was unable to attend due to the workload following the Kaikoura earthquake. Mark O'Connor kindly agreed to present on the NZ Transport Agency's behalf. Similarly, Garry McDonald (Market Economics) was unable to attend. Robert Caldwell kindly agreed to present on behalf of Market Economics.

Agenda

The agenda for the workshop is outlined below.

10:00 – 10:10am	Welcome and Introduction	Seosamh Costello (UoA)
10:10 – 10:30am	The National Science Challenge (NSC), QuakeCoRE and where Resilient Transportation fits in	Suzanne Wilkinson , Liam Wotherspoon and Seosamh Costello (UoA)
10:30 – 11:00am	NZTA Perspective on Resilience	Mark O'Connor on behalf of Stuart Woods (NZTA)
11:00 – 11:20am	Valuing Resilience in Infrastructure	Monique Cornish (T+T), Nathan Bittle (EY)
11:20 – 11:40am	Emergency Evacuation Modelling for Auckland	Prakash Ranjitkar (UoA)
11:40 – 12:00pm	MERIT for Transport	Robert Caldwell on behalf of Gary McDonald (Market Economics)
12:00 – 12.30pm	**Lunch**	
12.30 – 2.00pm	Workshop Sessions	All Attendees
2:00 – 2:15pm	**Afternoon Tea**	
2:15 – 4:00pm	Workshop Sessions	All Attendees

Presentations

Following the opening welcome, the University of Auckland team outlined the key objectives and agenda for the day. Research students and emerging researchers in the room were also introduced to the end-users and stakeholders present. An overview of the Resilience to Nature's Challenges National Science Challenge (NSC) and QuakeCoRE was then provided, followed by the key transport infrastructure objectives embedded in the programmes.

NZ Transport Agency then provided their perspective on transport resilience and an update on the issues following the Kaikoura earthquake. Tonkin+Taylor, along with EY, then outlined their research on valuing resilience in infrastructure – an NZ Transport Agency funded research project. The University of Auckland followed with a summary of the transportation modelling work they have been doing on emergency evacuation modelling for Auckland. Finally, Market Economics presented on their Spatial – MERIT decision support system and specifically the application to the Auckland transportation network.

Full copies of the presentations are attached as Appendix B.

Workshop Sessions

The workshop sessions opened with a list of questions/instructions relating to transport resilience as follows:

1. Document past, current and planned research or initiatives.
2. What are the key challenges in this area for transportation?
3. What research opportunities are there from this?
4. Identify your top 3-5.
5. Where might the funding come from?

The attendees formed four groups and tackled each question/instruction in turn. A lead member took notes on a flip chart and they reported back at the end of the sessions on their discussions. Post workshop a member of each group was asked to summarise the key outputs from their group for inclusion in this report.

Group 1 Workshop Outputs

Past Research

- Climate Change Effects on the Land Transport Network Volume One: Literature Review and Gap Analysis. NZ Transport Agency Research Report 378, 2009.
- Climate Change Effects on the Land Transport Network Volume Two: Approach to Risk Management. NZ Transport Agency Research Report 378, 2009.
- Measuring the resilience of transport infrastructure. NZ Transport Agency Research Report 546, 2014.
- Climate Changes, Impacts & Implications for New Zealand – CCII.org.nz
- Preparing New Zealand for rising seas: Certainty and Uncertainty. Parliamentary Commissioner for the Environment, November 2015.

Current Research

- RNC - Living at the edge
- Riskscape
- Hazardscape
- Canterbury technical database
- Valuing Resilience (NZTA)
- Spatial MERIT

Key Research Challenges/Opportunities

1. Web page to catalogue research/initiates/approaches to resilience, tools being used in practice, processes being used in practice – knowledge hub.
2. Frameworks for better community engagement and better decision making processes - understanding tolerance, acceptability of outage, willingness to pay. CCOs and councils need to turn that into decision making. Extension to “Living at the Edge – might need to extend to include transport explicitly. Community engagement with respect to transport not being thought about.

3. Work towards agreeing a NZ approach to valuing non-financial capital, e.g. social, cultural, environmental, and interdependencies between capitals. SROI natural capital protocol, hybridised LCA. Corporate interest. Transferable methodology required.
4. Better characterisation of how challenges evolve and interact over time – interaction or knock on effects, both positive and negative.
5. Better characterisation of challenges beyond natural hazards. Stresses and shocks interact with our ability to respond to such shocks. Organisational resilience/business resilience (and supply chain) and how it affects asset resilience.

<u>Other Research Opportunities</u>

- National LIDAR dataset
- National scale datasets

Group 2 Workshop Outputs

Past Projects

- NZTA Resilience projects – summary of this work collated by Stuart Woods
- Transportation component fragility for range of hazards – most of these dominated by international infrastructure that may not be representative of NZ construction.
- Economics of Resilient Infrastructure (ERI) and MERIT projects – South Island, Auckland, etc.
- NIWA and GNS collation of infrastructure
- Regional and National Lifelines groups projects and regional assessments.
- Hazard estimates – Robinson Landslide model.

Present Projects

- Riskscape – development and collation of component fragilities.
- NHRP – Coastal and storm related hazards project.
- QuakeCoRE/RNC – Infrastructure with urban and rural focus.
- AECOM – NZTA Level of service and customer service.
- NHRP – Tsunami and NZ bridge fragility.
- Deep South NSC – Sea level rise impacts.
- Callaghan – NZ Bridge seismic fragility.
- NZTA and OPUS – State highway multi-hazard assessment.
- GNS – Post Disaster cities.
- GNS – NZTA route assessment tool.

Future Projects – Top Priorities

1. Review of design code philosophies and how these link to community expectation of transportation network functionality. This requires enhanced community engagement and co-creation.
2. Development and application of monitoring strategies along corridors to better assess potential impact due to range of natural hazards. This includes slopes, bridges, river flow levels, etc. Methods for instrumentation and data processing need development.
3. Collate and analyse road rehabilitation data that has been collected post-Kaikoura earthquake. GPS data on vehicles, activity logs and economic data can be used to develop models that can be applied to future events.
4. Impacts of flooding on transportation. Performance of flood defence networks, effect of sediment accumulation, debris loading effects, impact of change in sea level and climate.

Future Projects - Other

- Built environment and transportation route interaction assessments, such as impact of collapsed structures.
- Temporal hazard and impact assessment methods needed to allow for assessment of the effect of future hazards on repair strategies.
- Application of lessons from Kaikoura for future Alpine Fault events.
- Assessment of existing resilience frameworks using data from the Kaikoura event as a case study.
- More focus on ports and the regional importance of these facilities in an economic and lifelines sense. A more national approach should be taken to the assessment of these facilities.
- Assessment of current emergency legislation and the impact of this on post-event actions.
- Impact of infrastructure on amplification of natural hazard impacts (such as increased flooding due to location of impermeable barriers).
- Impact of hazard events on tourism and the drivers that affect this.
- Impact of hazard events on freight – alternative routes and modes, national approach to mitigating these effects, collation of data.

- Development of NZ specific fragility models for earthquake, liquefaction, flood and tsunami.

Potential Funding sources

Outside of traditional sources, potential groups could be:

- Ngai Tahu
- Tourism NZ
- Lotteries Commission
- Fonterra
- Freight companies

In Australia tax breaks are available for industry research support – could this be investigated.

Need a clear mechanism for the translation of research into practice for all the above.

Embedding research students with stakeholders/consultants provides efficient mechanism for knowledge transfer and project development.

Group 3 Workshop Outputs

Current Research

- DEVORA Volcanic Research Group
    - Likelihood of eruption
    - Impact on transport
    - Future research
- Tsunami and coastal hazard modelling (NIWA)
- Geonet
- National seismic model with QuakeCore (GNS)
- Earthquake in Hauraki Rift (UOA)
- Flood models and high wind models (Auckland Council)
- Climate models (International sources)
- NZGD
- Liquefaction within Auckland
- Risk Scape
- Weather prediction modelling (Met Services)
- Wellington Slide/It's our fault

Policies and Guidance

- Local Government Risk Agency
- National Resilience Strategy + Local CDM plans
- Climate Guidance
- Natural Hazards NPS
- National Coastal Policy NPS
- City Resilience Strategies (Auckland, Wellington, Christchurch, etc)
- RES organizations
- BCP + Emergency Response Planning
- Lifelines
- Fuel Contingency Planning

Key Challenges and Research Opportunities – Top Priorities

1. Better sharing and understanding of spatial asset data such as utility services: It was raised in this group discussion that there is not sufficient understanding of spatial distribution of assets such as utility services in New Zealand. Such data shall be shared with stakeholders.
2. Is the Civil Defence Act working? There shall be better collaboration during and after an emergency: Concerns were raised on how different emergency response authorities collaborated during Kaikoura earthquake. Emergency response mechanism defined in Civil Defence Act, is it working?
3. Vulnerability of public transport system e.g. impact of volcanic ash on rail or unavailability of bus drivers: Public transport, being the most efficient transport mode for mass movement of people, we shall look into vulnerability of PT in emergency situations.
4. Limited understanding of human behaviour and how to formulate communication strategy in emergency (tools, network modelling …): Our understanding of how people would behave under emergency situations are limited hence most of research are based on a number of assumptions such as people will not panic and all driving rules will be followed, which might not be realistic. To formulate an effective communication strategy in emergency situation, we need better understanding of expected response of different strategies.
5. Discrepancies in terminology and methodology for risk, resilience, criticality, vulnerability: There are discrepancies in definition of terminologies such as risk, resilience, criticality, vulnerability in literatures and methodologies to measure them.

Others Research Opportunities

- Managing emergency stores for fuel, generators and other supplies and sharing and communicating where they are
- Incident responsiveness for small scale event such as accident
- Solid waste management after natural disaster
- Aggregate/bitumen supplies after natural disaster (need for bailey bridges, storage capacity)
- Enabling environment for incorporating technology
- How eruption affects visibility (possible extension of DEVORA work)

Funding Sources

- Ministry of Business Innovation and Employment (MBIE)
- Ministry of Transport (MOT)
- Ministry of Civil Defence and Emergency Management - CDEM Resilience Fund
- New Zealand Transport Agency (NZTA)
- International Collaboration
- Territorial Authorities
- Lifeline Utilities
- Kiwi Rail
- Ports/Airport Authorities
- Business Associations

Group 4 Workshop Outputs

Current Workstreams

- National Science Challenge - Resilience to Nature's Challenges
    - Infrastructure
    - Rural [Canterbury/West Coast/Hawkes Bay]
    - Urban [Auckland]
- MERIT
- NZTA Valuing Resilience (Hughes & Healy)
- NZTA Highway Assessment
- GNS Risk Evaluation Tool [Wellington]
- DEVORA [Auckland]
- CDEM Scenarios
    - Tangaroa (Tsunami)
    - Ruamoku (Volcano) [Auckland]
    - Te Ripahapa (Earthquake) [West Coast]
    - Cruickshank (Pandemic)
- QuakeCoRE
- Project AF8 [South Island + Wellington]
- Lifelines [Regional]
- Wellington Water
- Riskscape

Key Challenges/Research Opportunities

- Cascading infrastructure impacts: Investigating follow-on impacts from single infrastructure failure, and response strategies
- Population Changes : Anticipating and pre-empting future network capacity changes and needs
- Infrastructure shock events: How does infrastructure respond to a large shock (e.g. a natural hazard event)? Still more work to be done.
- Changing technologies, and how these will impact future network capacity needs (e.g. electric cars vs on-home battery storage)

- Viewing infrastructure more holistically: Investing in services, rather than assets, and viewing the outcome as (e.g.) transport, rather than looking at needing to improve roads.
    - Maximising co-benefits (e.g. Wellington Water can't provide water for fire-fighting post-earthquake, so is looking to subsidise fire extinguishers. Not "water" investment, but much more cost-effective than altering the whole water system for the same outcome. A service approach, rather than an asset approach).
    - Building redundancy
    - Moving beyond build-back
    - Multi-hazards
    - Multi-sector
    - Whole-of-life
    - Wider economic benefits
- Community post-disaster service expectations: How to communicate and adapt post-disaster infrastructure plans between communities and infrastructure stakeholders
- Identification of economic indicators following a disaster, beyond GDP and Employment
- Emerging Risks (BCP)
- Fast-moving goods
- How to put research into practice
- Linking up research
- Communication and engagement
- Practical measures/advice to be implemented now.

<u>Research Priorities</u>

1. Maximising co-benefits across infrastructure providers (service, not asset, focus) [$ Central Government]
2. Cascading infrastructure impacts [$ Lifelines]
3. Engagement and Communication [$ Universities, NZTA, EQC, MBIE, Councils, CDEM]
    a. Linking up research
    b. Practical measures/advice to be implemented now.

Dissemination

The research challenges and opportunities identified in the workshop include some that are transport specific, either directly or indirectly, and others that are wider than transportation. For example, some relate to key inputs required for modelling of transport resilience and others relate to the use of the outputs from a transport resilience assessment. Others again are far more generic. While a number of the challenges and opportunities will be best addressed within, or at least coordinated by, the transport stream of the Infrastructure Toolbox, many others are best addressed/coordinated elsewhere in the Resilience to Natures Challenges NSC or QuakeCoRE, or indeed the wider research community.

Consequently, while the intention is to circulate this summary report to all attendees and include it on the FP6: Distributed Infrastructure page of the UC Wiki, it is recommended that the workshop outputs are disseminated wider via the RNC and QuakeCoRE.

Summary of Research Priorities

A summary of the prioritised research challenges/opportunities is provided below. These are identified in greater detail in the various workshop sections above.

- Vulnerability of the public transport system in a disaster, given that it may be relied upon for evacuation.
- Creation of a resilience knowledge hub.
- Agreement on a New Zealand approach to valuing non-financial capital.
- Frameworks for better community engagement and better decision making processes - understanding tolerance, acceptability of outage, willingness to pay.
- Better characterisation of how challenges evolve and interact over time – interaction or knock on effects, both positive and negative.
- Organisational/business resilience (and supply chains) and how they affect asset resilience.

- The recent Kaikoura earthquake provides an opportunity to collate and analyse traffic data. Similarly for the post-earthquake road rehabilitation effort.
- Creation of a “one-stop-shop” for spatial asset data such as utility services.
- Is the Civil Defence Act working? Concerns were raised on how different emergency response authorities collaborated during the Kaikoura earthquake.
- Discrepancies in terminology and methodology for risk, resilience, criticality, and vulnerability.
- Review of design code philosophies and how these link to community expectations of transportation network functionality.
- Development and application of monitoring strategies along corridors to better assess potential impact due to a range of natural hazards.
- Limited understanding of human behaviour in an emergency situation and, therefore, how to formulate an effective communication strategy.
- Performance of flood defence networks, effect of sediment accumulation, debris loading effects and changes in sea level, and in particular their impact on the transportation network.
- Maximising co-benefits across infrastructure providers (service, not asset, focus).
- Cascading infrastructure impacts.
- Engagement and Communication - Linking up research and the identification of practical measures/advice to be implemented now.

Infrastructure Toolbox – Research Plan

The Resilience to Natures Challenges NSC Infrastructure Toolbox has recently funded two PhD students to undertake research in the resilient transportation space. One will be linking with the Urban Case Study and one with the Rural Case Study. This workshop has both confirmed the need for planned research and identified further research in this area, as outlined below.

Infrastructure - Urban

The presentation on Emergency Evacuation Modelling for Auckland received the greatest attention in terms of Q&A at the workshop and clearly engaged the audience. To date, limited modelling has been undertaken by final year undergraduate students and, consequently, the work relied on many unrealistic assumptions. It is therefore proposed to focus the Urban Transport Resilience PhD student's research in this area.

While the modelling itself presents many challenges in its own right, our understanding of human behaviour under emergency situations is limited, for example the level and extent of panic and whether all driving rules will be followed. Such scenarios can be modelled, if relevant data is captured, and this can lead to the development of an effective communication strategy for emergency situations based on a better understanding of the expected response to different strategies and resulting network performance.

In addition, depending on the time of day, the evacuation may rely on the public transport system - public transport being the most efficient transport mode for mass movement of people. However, the vulnerability of the public transport system (e.g. impact of volcanic ash on rail or unavailability of bus drivers) is not well understood.

Either or both of the above research challenges/opportunities identified in the workshop may become research projects in their own right, requiring funding and students. Such opportunities will be explored, but in any case the evacuation modelling needs to make explicit assumptions about both, with further research providing increased confidence in the assumptions.

Infrastructure - Rural

The Rural Transport Resilience PhD student's research will focus on a case study in Canterbury/West Coast to assess the resilience of the transportation network. The proposed hazard event is an earthquake involving the Alpine fault.

While post-disaster transport models can be developed and scenarios modelled, it is difficult to calibrate/validate such models. However, the recent Kaikoura earthquake provides an opportunity to collate and analyse traffic data from

stationary count sites, as well as activity logs and GPS data from heavy goods vehicles. Such data will assist with the calibration of the transport models. The earthquake also provides an opportunity to collate data on the road rehabilitation effort post-earthquake; thereby allowing for the spatial and temporal modelling of the loss and subsequent reintroduction of accessibility and service levels.

Finally, in order to assess whether the resilience of a particular transport route is acceptable, we need to get a better understanding of tolerance/acceptability of outage from providers and/or the community they serve. Such an understanding is key to resilience decision making.

Both of the above research challenges/opportunities identified in the workshop will be explored. The former will probably form part of a wider data collection strategy related to the Kaikoura Earthquake and distributed infrastructure, leveraging off potential short term funding through the NHRP.

Appendix A: List of Attendees

First Name	Surname	Organisation
Mujaddad	Afzal	University of Auckland
Mohammad	Aghababaei	University of Auckland
Michael	Allis	NIWA
Adam	Ashford	AECOM
Mark	Bebbington	Massey University
Nathan	Bittle	EY
Monique	Cornish	Tonkin+Taylor
Seosamh	Costello	University of Auckland
Mike	Costelloe	Downer
Alistair	Davies	University of Canterbury
John	Davies	JMAC AT
Temitope	Egbelakin	Massey University
Roger	Fairclough	National Infrastructure Unit
Casey	Giberson	Tonkin+Taylor
Theuns	Henning	University of Auckland
James	Hughes	AECOM
Vivienne	Ivory	OPUS Research
Jane	James	Kiwi Rail
Bruce	Kassir	Auckland Transport (JTOC)
Rothit	Lal	NZ Transport Agency
Rob	Cardwell	Market Economics
Mark	O'Connor	NZ Transport Agency
Prakash	Ranjitkar	University of Auckland
Ross	Roberts	Auckland Council
Vinod	Sadashiva	GNS Science
Peter	Scott	Auckland Transport
David	Spriggs	Downer
Prasad	Tala	NZ Transport Agency
Mitchell	Tse	Auckland Transport (ATOC)
Suzanne	Wilkinson	University of Auckland
Liam	Wotherspoon	University of Auckland

Appendix B: Presentation Slides

Resilience of Transport Infrastructure

Date: 1 December 2016
Venue: Pullman Hotel, Auckland

Seosamh Costello, Suzanne Wilkinson and Liam Wotherspoon

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Sponsors

THE UNIVERSITY OF AUCKLAND NEW ZEALAND | ENGINEERING

National SCIENCE Challenges | RESILIENCE TO NATURE'S CHALLENGES | Kia manawaroa – Ngā Ākina o Te Ao Tūroa

QuakeCoRE

Objectives

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- Create a network of researchers, stakeholders and end-users to help shape future research in this area.
- Encourage direct and active involvement of end-users and stakeholders in ongoing research in this area.
- Involve and introduce research students and emerging researchers to the end-users and stakeholders.

Introductions

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- Emerging Researchers and Students
  - Mohammad Aghababaei (Auckland), Mujaddad Afzal (Auckland), Alistair Davies (Canterbury), Temitope Egbelakin (Massey)
- Other RNC Researchers and Stakeholders
  - GNS, NIWA, OPUS, Massey, Market Economics, AECOM, Tonkin & Taylor, E&Y, Downer, FH
  - MoT, NZTA, Kiwi Rail, NIU, Auckland Transport, Auckland Council, Lifelines
  - …..have I missed anyone.

Objectives

THE UNIVERSITY OF AUCKLAND NEW ZEALAND | ENGINEERING

- Document past, current and planned research in this area……..and to develop a roadmap of the future research requirements along with possible funding sources.
- Use Resilience to Nature's Challenges/QuakeCoRE outcomes to help focus future research in this area in New Zealand.
- Explore the possibility of leveraging funding from stakeholders.

Agenda

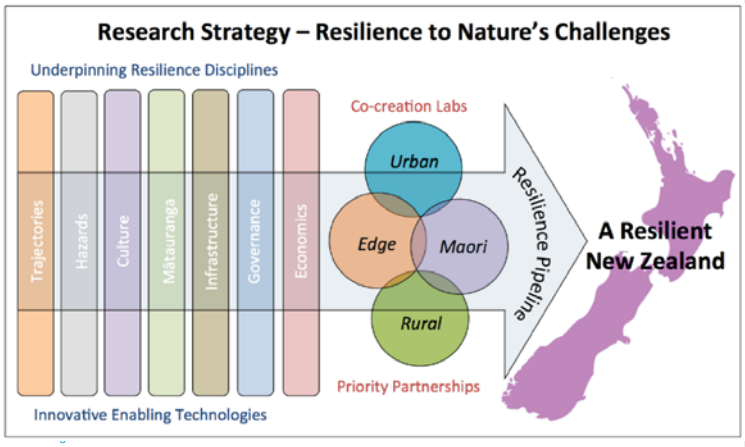
THE UNIVERSITY OF AUCKLAND NEW ZEALAND | ENGINEERING

12:00 – 12:30pm	Registration - Morning Tea	
10:00 – 10:10am	Welcome	Seosamh Costello (UoA)
10:10 – 10:30am	The National Science Challenge (NSC), QuakeCoRE and where Resilient Transportation fits in	Suzanne Wilkinson , Liam Wotherspoon and Seosamh Costello (UoA)
10:30 – 11:00am	NZTA Perspective on Resilience	Mark O'Connor (NZTA)
11:00 – 11:20am	Valuing Resilience in Infrastructure	Monique Cornish (T+T), Nathan Bittle (EY) and Sandy Fong (NZTA)
11:20 – 11:40am	Emergency Evacuation Modelling for Auckland	Prakash Ranjitkar (UoA)
11:40 – 12:00pm	MERIT for Transport	Garry McDonald (Market Economics)

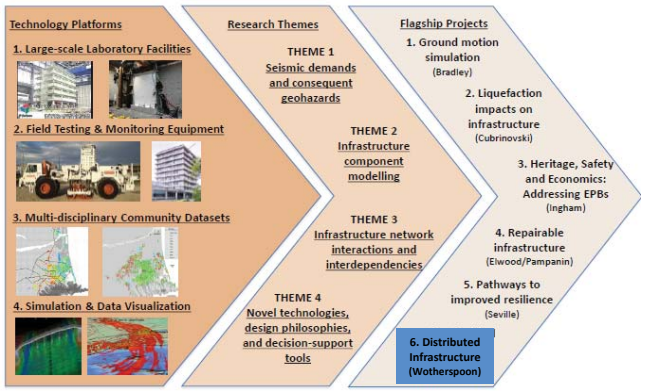
Agenda

12:00 – 12:30pm	Lunch	
12.30 – 1.00pm	Workshop Session 1	All Attendees
1:00 – 1:30pm	Workshop Session 2	All Attendees
1:30 – 2:00pm	Workshop Session 3	All Attendees
2:00 – 2:15pm	Afternoon Tea	All Attendees
2:15 – 2.45pm	Workshop Session 4	All Attendees
2:45 – 3:15pm	Workshop Session 5	All Attendees
3:15 – 4:00pm	Discussion and Close	All Attendees

RNC



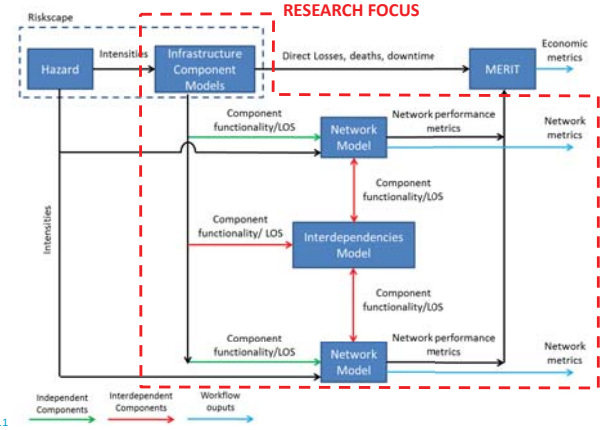
QuakeCoRE



Distributed Infrastructure

- Develop an improved understanding of the resilience of spatially-distributed infrastructure networks to extreme natural hazards
- Geologic and extreme weather related natural hazards
- Collaboration between Resilience to Nature's Challenges and QuakeCoRE

Distributed Infrastructure



Infrastructure

1. Case studies and relevant hazards identified
2. Infrastructure datasets acquired
3. Methodology developed to quantify damage to networks
4. Simulations performed to quantify damage to networks and service disruption – do nothing scenario
5. Simulations performed to understand pre-disaster mitigation and post-disaster actions to minimise service disruption – do something scenarios

Urban

1. NZTA Resilience Indicators tested on trial site in Auckland's transport network
2. Indicators tested broadly across the NZTA and AT transport network
3. Most vulnerable roads in Auckland's transport network identified

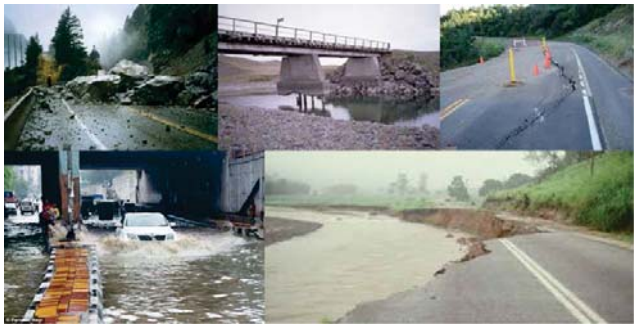
Thank You

NZTA Perspective on Resilience

New NZTA structure

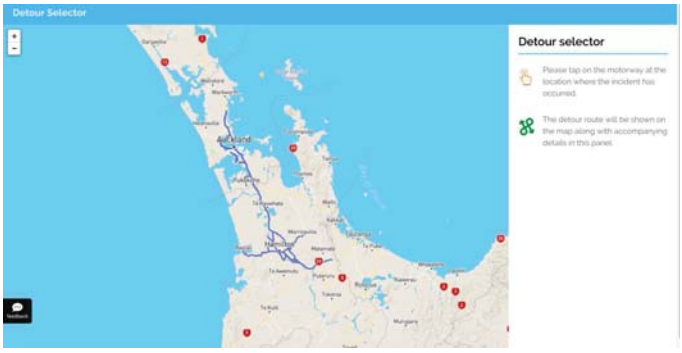
- Customer
- Cultural Change
- Safety
- Technology
- Economic prosperity
- Collaboration

Current process – Minor Resilience and Enhanced Resilience work categories.



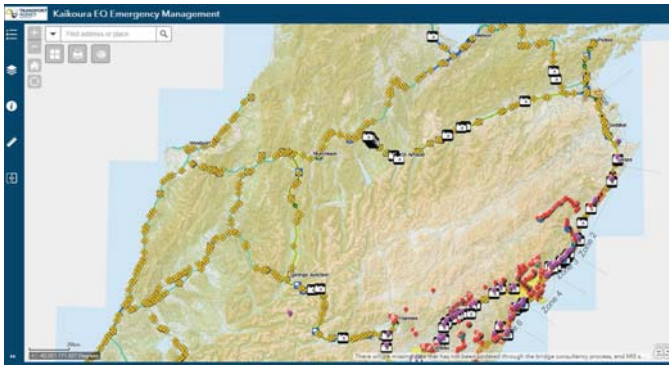
Resilience Project

Alternate Routes Tool



Highway Resilience Assessment

Dealing with the Kaikoura quake



Dealing with the Kaikoura quake

Valuing resilience in infrastructure

Monique Cornish, T+T and Nathan Bittle, EY



Acknowledgements

The project team acknowledge the valuable input from our Advisory Committee and Peer Reviewers:

- NZ Transport Agency: Sandy Fong, Stuart Woods
- Ministry of Transport: Ian Duncan
- National Infrastructure Unit: Roger Fairclough
- Local Governments: Russell Hawkes (Environment Southland), Mike Mendonca (Wellington City Council)
- Peer Reviewers: Erica Seville (Resilient Organisations), John Spiers (Arcadis)
- Project Directors: Chris Money (EY), Richard Reinen-Hamill (T+T)

Research need

- Resilience is a priority for transport
- Improving resilience is desirable
- Current assessment of resilience is subjective
  - What should we be resilient to?
  - Can resilience be valued?
  - How do we prioritise resilience improvements?



Objective & context

To develop a framework which supports the evaluation of different controls that aim to create an acceptable level of resilience in (transport) infrastructure – in the context of broader social, economic and environmental outcomes - as defined by stakeholders

Hutt Valley	Kaikoura	Tamaki Drive



NATIONAL DISASTER RESILIENCE STRATEGY: PRIORITIES

Priority Area 1: Improve the understanding of risk to enable better risk-informed decision-making

Focus Area #1 Data Collection, Management and Availability (incl geospatial) for DRRR
- Increased use of location-based info; risk mapping; geospatial policy
- National datasets, data standards
- Data sharing, data availability/accessibility, incl. real-time data
- Centralised national/local risk info portals
- National loss database

Focus Area #2 Improving our Risk Assessment Capability
- Improved/standardised risk assessment methodology, incl improved asst of exposure and vulnerability
- Evaluation of multi-capital impacts (e.g. economic cost of social impacts)
- National risk assessment
- Identify high-hazard/high-risk communities
- Tools for improved risk modelling and forecasting, including system trends
- Support LGRA

Focus Area #3 Defining Risk Tolerance and Acceptability
- Research/advice
- Guidance for risk tolerance/acceptable risk
- Orgs to define risk tolerance

Focus Area #4 Improving the Way we Communicate Risk for Improved Risk Literacy
- Risk comms research into policy/practice
- Guidance on risk comms
- Updated hazardscape
- National risk conversation(s)

Focus Area #5 Tools and Resources to Enable Decision-making
- Multi-capital decision making tools
- Case studies of cost-benefit of risk reduction as part of toolkit to persuade decision-makers
- Methods for quantifying and pricing risk

Priority Area 2: Reduce existing risk and minimise the creation of new risk

Focus Area #6 Asset Risk Management for Resilience
- Resilience measures in council 30-year asset management plans
- Support the Built Environment Action Plan
- LGRA
- [??]

Focus Area #7 Tackling Retreat and Relocation
- National policy
- Local policies
- Public/community conversations about

Focus Area #8 Integrating Climate Change Adaptation with Mainstream HRM
- Support/implement Natural hazards NPS
- [??]
- [??]

Focus Area #9 (Incentivising) Resilient Development
- Improving the District Plan process
- Other land-use planning improvements/ initiatives
- [??]
- Insurance incentives for resilience
- Target audiences: Developers, Planners, etc
- Resources for 'making resilience easy'

Focus Area #10 Risk Financing, Transfer and Insurance
- Financial instruments for resilience
- Insurance products that support/encourage resilience
- National position on reinstatement
- Financial planning for long-term adaptation
- Guidance for local authorities on risk transfer strategies
- Other [??]

Priority Area 3: Strengthen resilience, both planned and adaptive

Focus Area #11 Individual and Household Resilience
- Emphasis on the most vulnerable incl. low/no income earners
- Making risk reduction/resilience easy

Focus Areas #12 Business and Organisational Resilience
- Promote the role of the private sector in resilience
- Make business continuity management simple
- Promote adaptive resilience practices
- Organisational resilience objectives in strategic plans
- Organisational risk/resilience objectives in job descriptions/performance agreements

Focus Area #13 Community Resilience
- National/local coalitions for community resilience
- Community development practices
- Vulnerable people and groups
- Rural resilience advice/advisors
- Marae preparedness

Focus Area #14 City/District Resilience
- Local authority resilience strategies
- City resilience framework/guidance
- Case studies
- Chief Resilience Officers

Focus Area #15 Readiness for Response
- Public alerting
- Crowd sourcing and citizen science to inform response management

Focus Area #16 Readiness for Recovery
- Strategic recovery planning
- Readiness for reconstruction

Priority Area 4: Build a culture of resilience

Focus Area #17 Governance and Leadership
- Governance mechanism for this Strategy
- Review local and regional governance arrangements
- Engaging elected representatives
- Integrate learnings from resilience-related research platforms (NSC, QuakeCORE etc)
- Resilience objectives in local authority strategic plans
- Oversight of high-hazard/high-risk communities by local/regional/national governance bodies
- Networks for resilience
- Integrate the private sector into public sector governance arrangements for risk/resilience

Focus Area #18 Embracing our Diversity and Building our Cultural Capital
- MCDEM to create a national kahui to provide input into resilience programmes and policy
- Resilience strategies should include indigenous knowledge/worldviews
- Civic education
- Nationhood
- Culture/heritage

Focus Area #19 New Technology for DRRR
- Working group for future foresight: process to envt scan new innovations in DRRR
- Keeping in pace with social media and information needs

Focus area #20 Outreach and Education
- Knowledge building of govt officials, civil society, communities, volunteers, private sector
- DRRR in school curriculum
- DRRR in vocational education
- Resilience advisors and other targeted, customer-focussed advice

NB. Each focus area will have a number of generic and specific actions aimed to triangulate to provide progress over the 10 year period

DRAFT: NOT GOVERNMENT POLICY

A consolidated definition

Resilience is the ability of systems (including infrastructure, government, business and communities) to proactively resist, absorb, recover from, or adapt to, disruption within a timeframe which is tolerable from a social, economic, cultural and environmental perspective

(adapted by project team for NZTA from USDHS 2009a in AECOM 2015)

Resilience is not restricted to natural hazards: resilience to organisational or systemic challenges is equally important
- Provide for a spectrum of stresses and shocks (the former is often under-estimated)

Confirmed resist, absorb, recover, adapt are the outcomes of resilience and form the basis for the taxonomy

Including tolerance allows the resilience of the system to be placed in the context of the communities value of the function of the system

Takes a wide view of value (which can be weighted if desired, and also allows the inclusion of wider economic benefits)

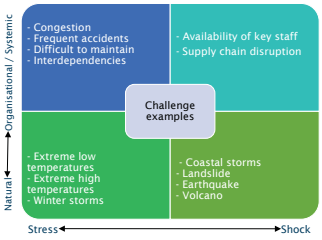
Focuses on outcomes of the system (e.g. level of service provided) versus *outputs or components* of the system

Resilience should be proactively sought as an outcome of decisioning

A consolidated taxonomy

An infinite number of scenarios could disrupt a transport network and an equally inordinate amount of controls are available to lower this risk

Challenges: the universe of challenges is large and includes four main dimensions (which work together to form a challenge matrix)



Resilience measures

Controls are equally numerous, but can be transport-centric or non-transport. Overall controls fall into four main categories

Tool overview

Supports the evaluation of different controls that aim to create an acceptable level of resilience in (transport) infrastructure – in the context of broader social, economic and environmental outcomes - as defined by stakeholders

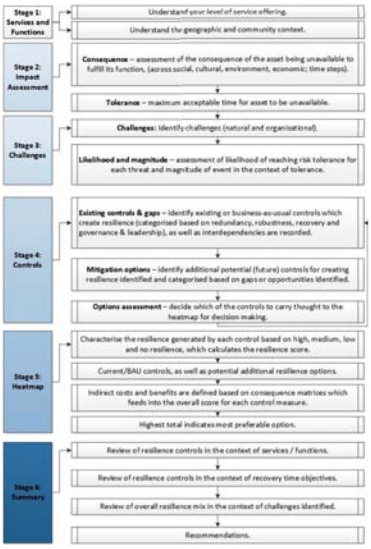
Practical: end-to-end solution for evaluating and responding to risk which can be integrated into existing (NZTA) processes

Leverages work undertaken to-date: explicitly allows for maturity / progression of approach (effort) over time

Outcomes focused: puts the function of assets within a system at the heart of decisioning and focuses on the consequences of assets not being available to users(i.e. not being resilient)

Community focused: allows for a range of stakeholder perspectives to be included in decisioning

Scalable: can be used in other sectors, system versus asset-specific, and can be used to compare investments across different regions



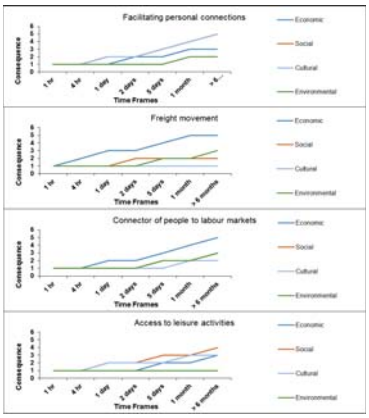
Decision support tool

Petone Esplanade & Waione Street Bridge Case Study

Context

Petone Esplanade & Waione St Bridge

- ***Critical Functions***:
  - Facilitating personal connections
  - Freight movement
  - Connecting people to the labour markets
  - Access to leisure activities
- ***Overall Recovery Time Objective***: 24-hours at 50%
- ***Key Challenges***: Winter Storms, Congestion, Flooding



Heatmap

	Control	Primary Characteristic	Flooding	Challenge	Challenge	Challenge	Challenge	Challenge	Challenge	Environment	Social	Cultural	Economic	Environment	Social	Cultural	Economic	Total	Cost of control	Source
C6	Current	Stop banks	L	L	H	L	L	L	M	M	L	L	L	M	M	L	M	25	TBC	TBC
C5	Current	Recovery contracts	M	L	L	L	L	L	L	L	L	L	L	L	L	L	M	23	$0	
C7	Current	Capacity improvements	L	M	L	L	L	M	M	M	M	M	M	L	L	L	M	23	$20-30m	SH2 Ngauranga – Te Mervo PBC
C8	Current	Recovery contracts	L	L	L	M	M	L	L	L	L	L	L	L	L	L	L	24	$0m	Estimate
C9	Future	Communication around working	H	L	H	L	L	L	L	L	L	L	L	L	M	L	M	28	$0.5m	Estimate
C4	Future	Land use change	L	M	L	L	L	L	M	M	M	M	M	L	L	L	L	24	$0m	Estimate
C6	Future	Cross Valley Link	M	M	L	M	L	M	M	M	M	M	L	L	M	M	M	27	$70m	CVL Strategic Case
C1	Future	Barge Landing	M	L	M	M	M	M	M	L	M	L	L	L	L	L	M	6	$10m	Estimate

Two new measures score the highest on the total resilience score

- Explore **communication tools** to encourage people to work from home during emergencies.
- Explore **CVL** further

Controls don't materially help mitigate against the challenges the asset is most exposed to

Other controls should be considered

- Further **recovery contracts**
- Higher cost options such as a **barge landing** require considerably more investigation if they are to be justified on resilience grounds alone

Controls recommended focus on **Robustness** and **Recovery** in particular

Next steps

Future Focus Areas

Test

- Opportunities to put research into practice: testing of tool under different scenarios and sensitivity assessment

Implement

- Implementation of tool and development of business rules for NZTA
- Opportunities to works with other asset class owners and organisations

Improve

- Data integration and automation
- Community engagement: ways of effectively engaging with communities to understand tolerance to outage and willingness to pay
- Better measurement of indirect costs and benefits: particularly considering the method to calculate travel time reliability (federal buffer zones)
- Network assessment: consider developing further to be used across a network

Appendix A

Definitions

Redundancy

Provision of functionally similar outcomes, to an acceptable standard, during lost or degraded levels of service

This definition includes important elements of:

Function: Decision makers need to be fully aware of the function (level of service) of the asset in question.

Outcomes: Decision makers should be aware of the outcomes they are trying to provide for – not just focusing on the provision of new assets.

Acceptable standards: Understanding the threshold of community acceptability is important.

There may not always be a clear understanding of function/outcomes – but seeking the views of affected parties / communities of interest and network users will get us closer to this answer.

Scenario: Based on consultation with the local community, it was determined that one bridge predominately provided access to a rural school the community relied upon.

Primary outcome(s): Student participation in class

Options to create redundancy:

- Development of an additional route (bridge) to the school
- Provision of tablets to students to allow them to work from home
- Arrangement with the local hall to provide alternative accommodation should the bridge fail

Robustness

The ability to withstand disruption and continue to provide to an acceptable level of service

Characteristics:

Well conceived, constructed and managed **systems**

Includes the implicit concept of **robustness of a system**, as well as the physical characteristics of an asset under normal circumstances

Anticipates failure

Acceptable level of service allows for resilience measures to include the option of returning partial function of an asset/system within a certain time period based on tolerance of communities of interest

Scenario: Inland ports are becoming an important to step in the aggregation of freight for export, and there is particular reliance on the Timaru / Lyttleton link for the Port of Lyttleton.

Primary outcome(s): Provision of cost effective bulk transport from freight services via rail from Timaru to Port of Lyttleton

Options to create a robust system:

- Structural: additional drainage and bunding along the line to withstand more intense rainfall events
- Organisational: development and implementation (including audit) of a maintenance regime of a frequency which ensures the line can function in marginal temperatures

Recovery

The ability to restore an acceptable level of service after disruption

This definition includes important elements of:

Acceptability: Decision makers need to be fully aware of the acceptability of an loss of service for the asset in question.

Service: Decision makers should be aware of the service (outcomes) they are trying to provide for – not just focusing on the provision of new assets.

Ability: Restoration of service must be within the bounds of control of decision makers.

There may not always be a clear understanding of acceptable levels of service provision for a particular asset/part of the transport system – but consultation with local communities and network users will get us closer to this answer.

Scenario: A landslide occurs on SH2 near Kaikoura.

Primary outcome(s): Restore one lane to full operation within 1 day – as this will have marginal costs for freight, business and the community. It has been determined, that more than one day creates unacceptably high costs and risks for freight delivery and the affected community.

Options to improve recovery:

- Prior consultation with a community about the acceptable levels of outage on the asset
- Prior discussions with contracting companies – who have geographically diverse access to any disruption – to ensure that service can be restored regardless of where a landslide might take place
- Prior consideration of feasible traffic diversions (if relevant)

Governance and Leadership

The ability to develop an organisational mind-set / culture of enthusiasm for challenges, agility, flexibility, adaptive capacity, innovation and taking opportunity*

Characteristics:

Leadership actively creates and supports the culture

Forward looking: The ability to identify, prioritise and address problems (also termed resourcefulness or situational awareness)

Responsive: capacity building to aid recovery and restoration (also termed rapidity)

Scope includes NZTA, organisations in NZTA's supply chain and communities of interest

Scenario: The Haast / Jackson Bay Road has overtopped more frequently in the last 5-years than the previous 20-years. The road is the only link between Haast and the small communities to the south.

Primary outcome(s): Provision of route to transport goods and fuel south of Haast

Options to support resilience from a governance perspective:

- Structural: encourage innovation within the engineering community to develop a surface that is less affected by brackish water
- NZTA: work collaboratively with subject matter experts to better understand the perceived increased frequency of events in the context of a changing climate to inform a response
- Community: formalise current approaches to fuel and goods storage so the community is not disrupted by overtopping events.

Definition of Terms

This glossary defines the specific meaning of certain words and phrases used in the public domain with regards to risk & resilience. In order to create a common understanding of risk & resilience, these terms should be used purposefully to mean the definitions provided. Where a different meaning is intended, a different word should be selected in order to begin to harmonise the lexicon of risk & resilience.

Where there is a New Zealand government defined definition, we have provided this *verbatim*, otherwise sources of the definitions have been included for reference.

Assets (at risk): Includes populations, systems, communities, the built domain, the natural domain, economic activities and services, trust and reputation; and other things we value which are under threat from hazards in a given area. This can also be described as elements (at risk)[1].

Communities of Interest / Affected Communities: Communities who are impacted by, or depend on, the transport system.

Consequence: An outcome of an event (that may result from a hazard) affecting objectives[2]. It may be expressed quantitatively (e.g. monetary value), by category (e.g. high, medium, low) or descriptively. An impact on the natural, economic, built or social environment as the result of a hazard event. Consequences are influenced by the exposure and vulnerability of elements at risk (e.g. human like and property) to the hazard, and by the hazard characteristics.

Cultural: To develop through model testing

Disruption: To develop through model testing

Economic: To develop through model testing

Definition of Terms

Environmental: To develop through model testing

Exposure: People, property, systems, or other assets present in hazard zones or exposed to hazards that are thereby subject to potential losses.

Frequency: A measure of likelihood expressed as the number or rate of occurrences, usually for a given time period[3].

Hazard / Threat / Challenge: A potential damaging physical event, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption, or environmental damage[1(modified)].
All challenges are covered by this term, e.g. malicious, technological, natural etc. Hazards can be single, sequential or combined in their origin and effects. Each challenge is characterised by its timing, location, intensity and probability[4].

Likelihood: The chance of something happening[2]. This can be expressed as probability either quantitatively as a ratio (e.g. 1 in 10), percentage (e.g. 10%) or value between 0 and 1 (e.g. 0.1) or qualitatively using defined and agreed terms such as unlikely, almost certain, possible etc[5(modified)].

Mitigation: The lessening or limitation of the adverse impacts of challenges[1].

Residual Risk: The risk that remains after risk treatment has been applied to reduce the potential consequences[4].

Resilience: The ability of systems (including infrastructure, government, business and communities) to proactively resist, absorb, recover from or adapt to disruption within a timeframe which is tolerable from a social, economic, cultural and environmental perspective.

Definition of Terms

Resilience Controls: To develop

Risk: The effects of uncertainty on objectives[2].

- an effect is a deviation from the expected (positive and/or negative)
- risk is often characterised by reference to potential events and consequences, or a combination of these
- risk is often expressed in terms of a combination of the consequences of an event (including changes in circumstances) and the associated likelihood of occurrence.

> Modern thinking on risk, as set out in ISO 31000, provides a particularly helpful approach to dealing with actual and potential threats and opportunities. One of the key paradigm shifts in ISO 31000 is a change in how risk is conceptualised. The definition of "risk" is no longer "chance or probability of loss", but "the effect of uncertainty on objectives" ... thus causing the word "risk" to refer to positive possibilities as well as negative ones. Risk therefore needs to be considered in the context of objectives (i.e. the function or provision of service within a system).

Risk Treatment: Measures taken to reduce the consequences of a hazard (e.g. through risk avoidance, reduction/mitigation, transfer or retention/acceptance). Cannot typically remove all risk[4].

Shocks: Sudden, sharp events that threaten a system, such as earthquakes, floods, disease outbreaks and terrorist attacks[6].

Social: To develop through model testing

Definition of Terms

Stresses: Longer term challenges that weaken the fabric of a system[6(modified)].

System: The 'system' includes both the transport network and the communities that depend on the system.

Tolerance: community of interest acceptance to an asset being unavailable, or available at reduced capacity, for a defined period of time.

Uncertainty: The state, even partial, of deficiency of information related to, understanding or knowledge of an event, its consequences or likelihood[2].

Vulnerability: The characteristics and circumstances of elements of risk (e.g. human life, asset or property) that make them susceptible to, or protected from, the damaging effects of a hazard[5].

1.UNISDR
2.ISO 31000
3.AGS (2000)
4.Provided by MfE, March 2016
5.LGNZ (2014) Managing natural hazard risk in New Zealand – towards more resilient communities. October 2014
6.Rockefeller Foundation

Appendix B

Literature cited

Literature Review

Around 100 reports identified
- 16 pieces of key literature considered in detail
- 75 pieces of other literature cited

Wide range of definitions of resilience – although there are number of common threads
- Researchers working on the *Resilience Benchmarking and Monitoring Review* accumulated 120 distinct definitions of resilience from peer-reviewed academic literature and policy and industry literature

A constantly evolving wealth of well-researched, well-reasoned, contributions to the resilience body of literature already exists - New Zealand also has a lot of good discrete contributions - but nothing that pulls all of this together

Limited economic assessment of wider costs or broader (indirect) benefits

Limited consideration of localised 'tolerance' towards disruption
- Bruneau et al. (2003) refer to the 'quality of infrastructure for a community sitting between 100% and 0%' - i.e. contemplates a scalable assessment of community dependence on assets.
- State Highway Network Resilience National Programme explicitly refers to 'understanding the vulnerability of communities to disruption'

Strong focus on shocks rather than stresses – natural hazards often drivers for research

EMERGENCY EVACUATION MODELLING FOR AUCKLAND

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Transport Resilience Workshop, 1st December 2016

Need for Auckland's Evacuation Plan

Hazards	Expected number to be displaced	Risk rating	Evacuate
Volcanic Eruption	100,000	High	Yes
Earthquake	10,000	High	Yes
Lifeline Utility Failure	100,000	Very high	No

Source: Civil Defence's Auckland Evacuation Plan (2010)

- Auckland, the largest city of NZ, is located on an active volcanic field - Auckland Volcanic Field (AVF)
- Volcanic eruption is identified as a high risk hazard for Auckland with large scale evacuation needed
- The impact of volcanic eruption can be catastrophic for safety and economy
- Uncertainty in volcano behaviour - estimates on warning time range from a day to a week

Past Studies

Artists impression of a Manurewa volcano

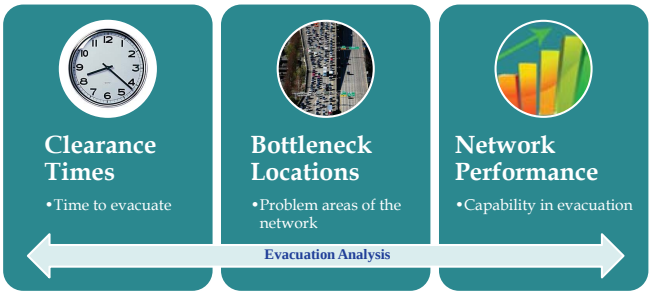
Exercise Ruaumoko '08

- National disaster exercise / public surveys
- Assessment of strategic planning
- 48 hours notice required to evacuate 5 km radius zone (Lindsay et al., 2010) - simply a postulation without reasoned backing

Tomsen's Thesis (2010)

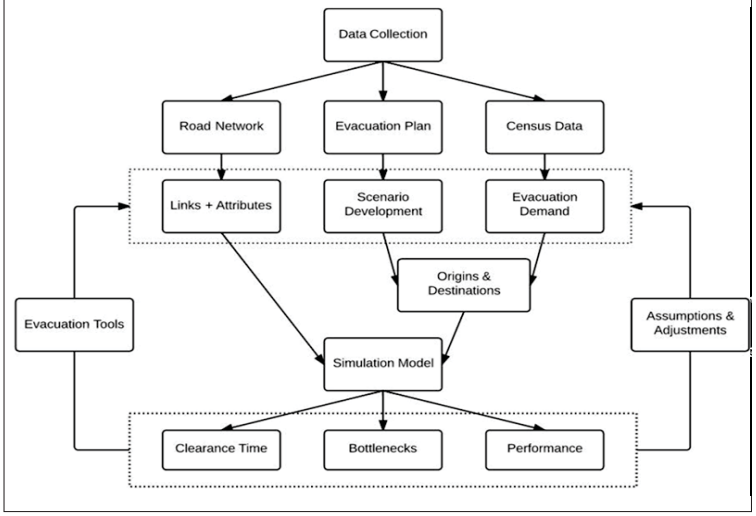
- Strategic level evacuation plan
- GIS based modelling using TransCAD
- Major gridlock experience with infinite clearance time – inconclusive results
- More detailed model required

Research Objectives



- Determine a total clearance time
- Locate bottlenecks and high congestion areas in Auckland road networks during evacuation
- Investigate the effectiveness of traffic control strategies during evacuation
- Investigate selected traffic control measures such as contraflow to reduce clearance time

Methodology



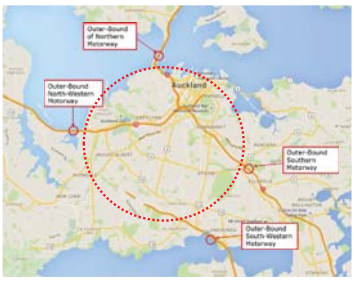
Methodology

Evacuation Scenarios

Time	Vehicle Number	Assumptions
Night	Single	• Evacuees won't panic (Dombroski and Fischoff, 2006) • Road Rules will be followed • Selection of destinations • No background traffic
	Multiple	
Day	Occupancy based	• 30 people per bus • People with no private vehicles, schools/university population uses buses

Study Area

For the worst situation, the eruption is assumed to be located 1 km south-west of Mt Eden with 5 km radius of the affected area.



Methodology

- Origin and destination
  - Each suburb is considered a zone
  - Auckland contains 411 zones
    - 66 origin zones within the evacuation area
    - 347 destination zones
- Night Time Single Vehicle Scenario

$$\text{Vehicle Demand} = \sum H + \left\{\frac{\left(\frac{L}{H+L}\right)\times P}{30}\right\}$$

- Night Time Multiple Vehicles Scenario

$$\text{Vehicle Demand} = \sum_1^3 (H \times n) + \left\{\frac{\left(\frac{L}{H+L}\right)\times P}{30}\right\}$$

- Day Time Scenario

$$\text{Vehicle demand} = \sum_1^3 (H \times n) + \frac{(W_i - W_o)\times(1-M)}{Oc} + \frac{(W_i - W_o)\times M}{30} + \frac{E}{30} + \frac{\left(\frac{L}{H+L}\right)\times(P-S)}{30}$$

H = number of households with vehicle(s)
n = number of light vehicles
L = number of households with no access to light vehicles
M = mode share of bus
P = total population within affected area
W_i = workers going towards affected area
W_o = workers going out of affected area
O_c = occupancy rate of private vehicles
E = enrolments in affected area
S = students living in affected area

Trips Generated

Scenarios	Trips Generated
Night Time (Single vehicle per household)	76,239
Night Time (Multiple vehicles per household)	130,110
Day Time (Multiple vehicles per household)	169,226

Modelling of Auckland Road Network

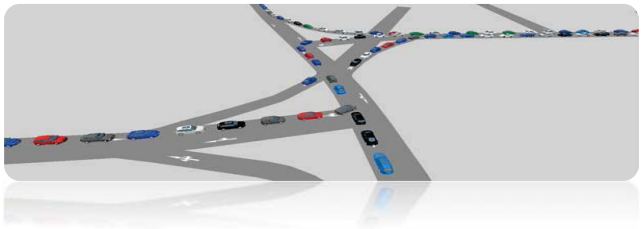
VISSIM, VISUM and AIMSUN

- Import Network
- Define Attributes
- Establish Simulation Parameters

Modelling in VISSIM (2014)

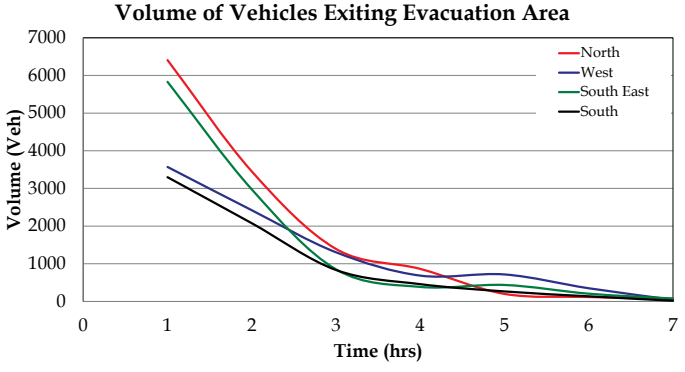
Limitations
Over 24 hours simulation time
10 simulations required for convergence

Results
Congestion on connector roads
Motorways free flowing



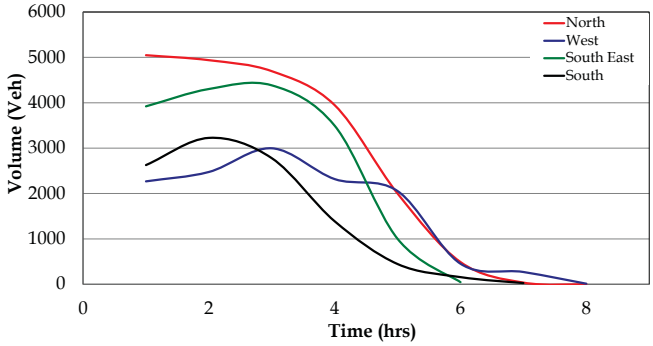
Results using VISUM

Night Time (Single Car) Scenario



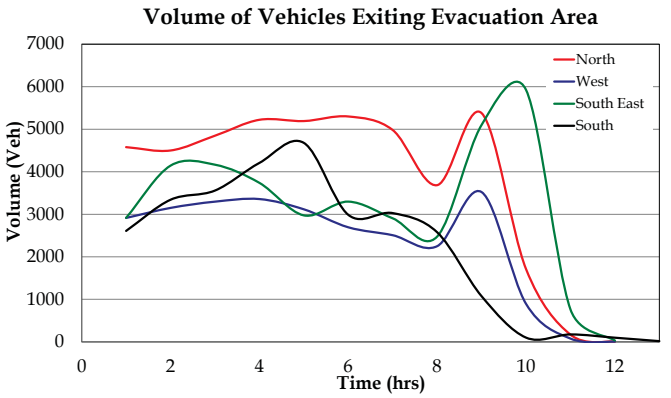
Results using VISUM

Night Time (Multiple Cars) Scenario

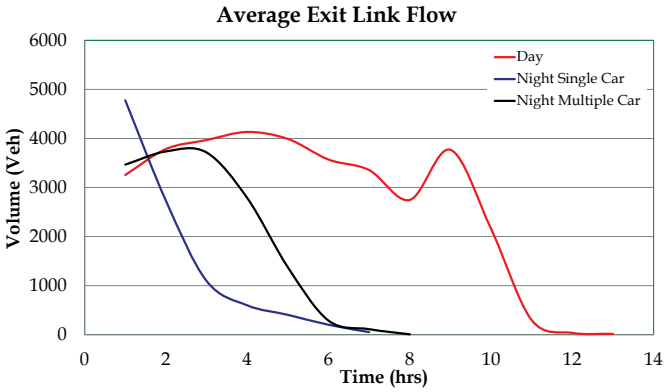


Results using VISUM

Day Time Scenario



Results using VISUM

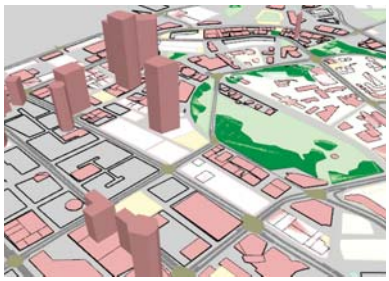


Modelling using AIMSUN

- Hybrid simulation tool
- Different platform and overview
- Can import Osm files
- Increasing usage in NZ

Building The Network

- Importing osm files
- Defining road network
  Arterial and main collector roads
- Lane configuration
  Number of lanes, turning bays, give-ways
- Road attributes
  Speed, Name and classification
- Actuated signal controls
- Origin – demand matrix



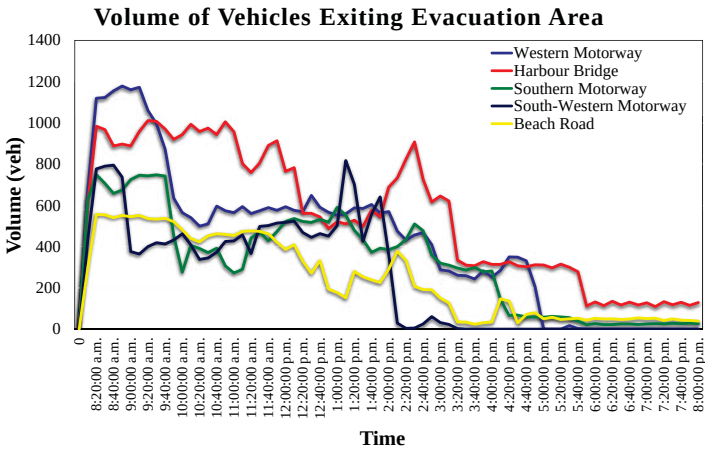
3-D Image of Auckland CBD in AIMSUN

Modelling using AIMSUN

- Dynamic Scenario
- Microscopic Simulation
- As soon as possible (ASAP) vehicle arrival rate
- Stochastic route choice

Results using AIMSUN

Day Time Scenario



Network Performance Results

Day Time

Link Speed (First Hour) | Link Speed (Sixth Hour) | Link Speed (Tenth Hour)

Note: Red colour indicates links with speed below 5km/hr

Key Findings

- Total clearance time for worst case scenario (day time) is estimated to be between 10 and 12 hours
- The south-western motorway (#20) is under utilized
- North motorway exit (Harbour bridge) had the greatest demand (30% of all evacuating vehicles)
- Congestion is observed near motorway on-ramps

Future Research Directions

- Locate bottlenecks and high congestion areas in Auckland road networks during evacuation
- Investigate the effectiveness of traffic control strategies during evacuation
- Investigate selected traffic control measures such as contraflow to reduce clearance time

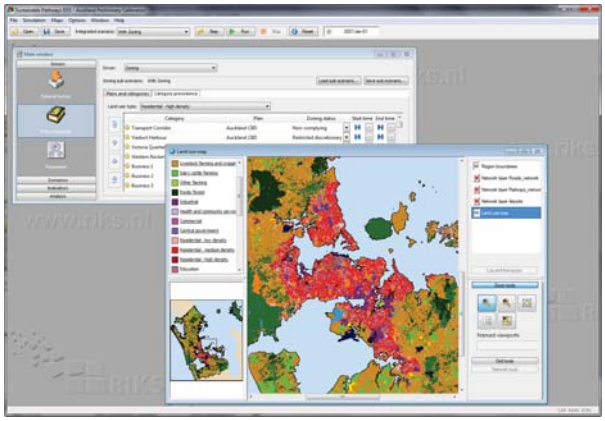
Spatial-MERIT

- A spatially explicit and dynamic decision support system for assessing the economic impacts of hazards and infrastructure failure
- Runs in two different modes:
  - Normal: baseline calculation of the spatially-explicit socio-economic developments
  - Shock time: impacts of an outage on transport and the economy
- Allows for assessing impact of hazard and infrastructure failure now and into the future

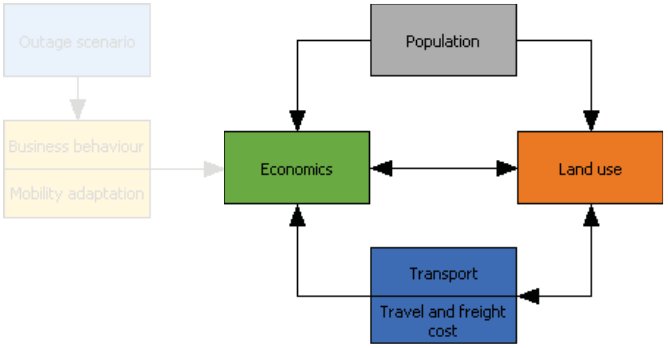
Characteristics of Spatial-MERIT

- Incorporates a spatially explicit integrated model including economics, demographics, land use and activities and transport
- Includes external drivers and policy options affecting on impacts of outages
  - Different regional socio-economic developments
  - Different spatial planning and infrastructure options
- Time horizon 2050
- Spatial extent Auckland, spatial resolution 100 m

Model Interface



The model in 'normal' mode



Population

- Age cohort model
- Calculation of the population per age cohort based on birth, mortality and migration rates
- Annual time step

- Provides input for
  - Economic model: labour force
  - Land use: total population

What is 'the' land use?

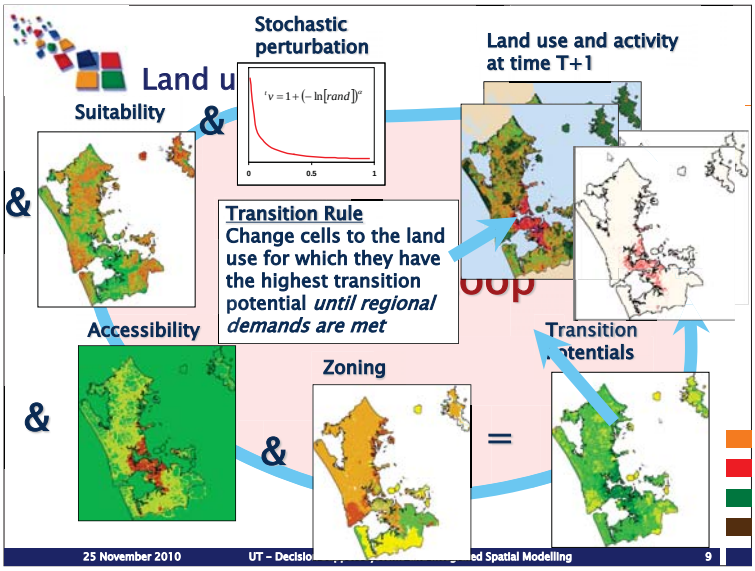
Activity based approach

- Cells have an activity and a land use:

LU	Activity 1	Activity 2	Explanation
	& (81)	& (22)	Residential area with 81 inhabitants and 22 jobs
	& (6)	& (2)	Agriculture with 6 inhabitants and 2 jobs

Activity based land use model

- Activity based cellular automata model
- Calculates land use map and maps with activity levels per cell (density maps)
  - Population
  - Employment (business and personal services, education, retail and hospitality, manufacturing)
- Provides input for
  - Economic model: unallocated economic demands
  - Transport model: location of activities and land uses

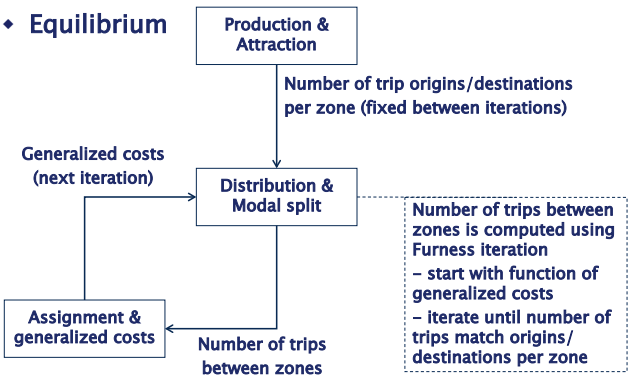


Transport

- Four-step transport model
- Calculates traffic flows from each transport zone to each other transport zone
  - Time, distance (per zone)
  - Intensity and congestion (on the road network)
- Provides input for:
  - Land use model: accessibility for allocation of businesses, residents and other activities
  - Economic model: transport costs for businesses, households and freight

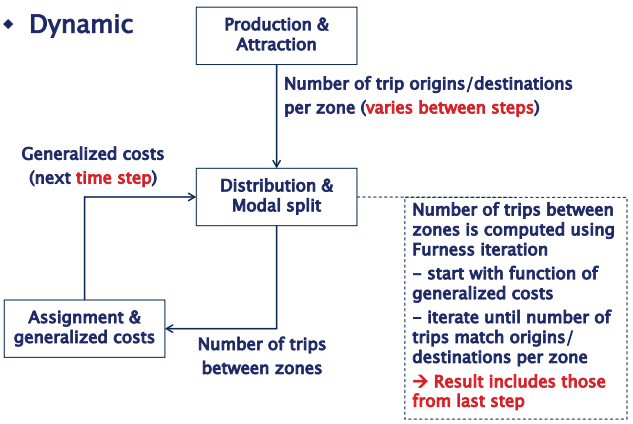
From classic 4-stage to dynamic

- Equilibrium

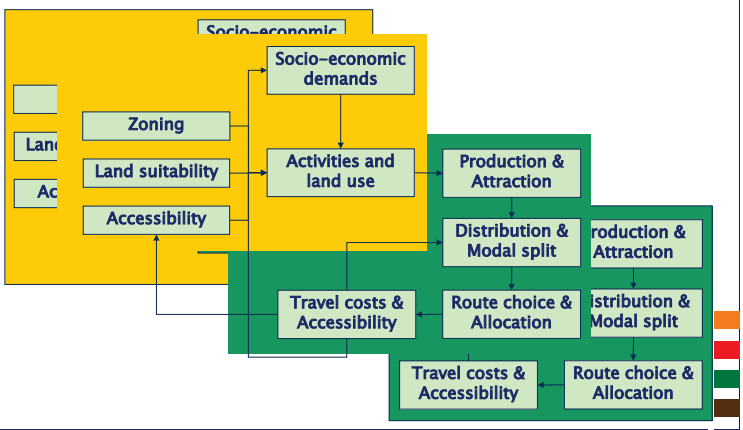


From classic 4-stage to dynamic

- Dynamic



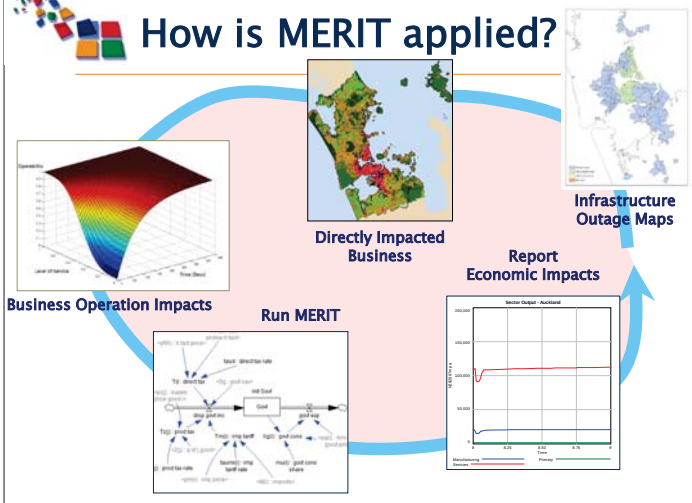
Integration land use and transport



Measuring the Economic Resilience of Infrastructure Tool (MERIT)

- Dynamic economic model (CGE) assessing economic impacts of infrastructure outages
  - Economic interdependencies, cascading effects, feedbacks and lags
  - Business resilience adaptations and response options
- *Resolution*: multi-regional (all regions), temporal (daily time-steps, 20yr horizon), multi-sectoral (80+ industries)
- *Reports:* Changes in GDP, employment, income, labour/capital markets etc

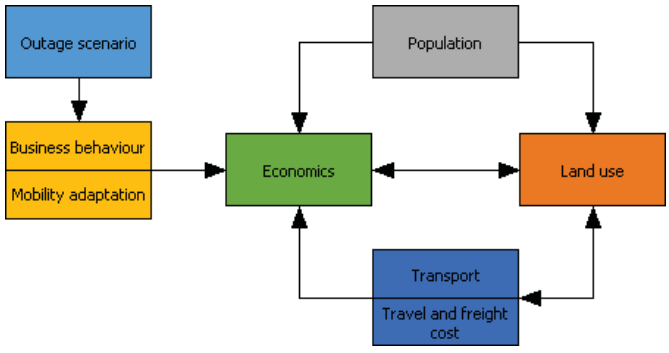
How is MERIT applied?



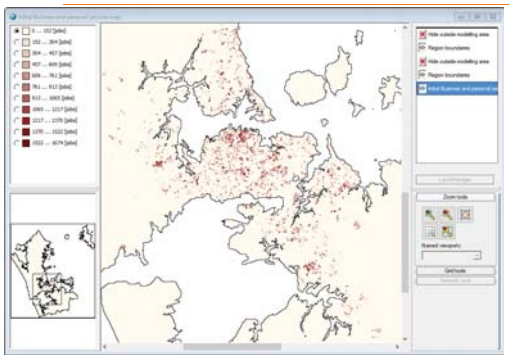
Where has MERIT been used?

- Transport
  - NZTA (Manawatu Gorge, SH2, online tool), MoT SH4 outage
  - Lyttelton Port, Ports of Auckland
- Electricity
  - Vector/Transpower
- Water/Sewerage
  - Watercare Services, Wellington Water
- Multi-infrastructure outage events
  - Alpine Fault, Auckland Volcanic Eruption, Wellington Resilience Business Case, *Kaikoura Quake*

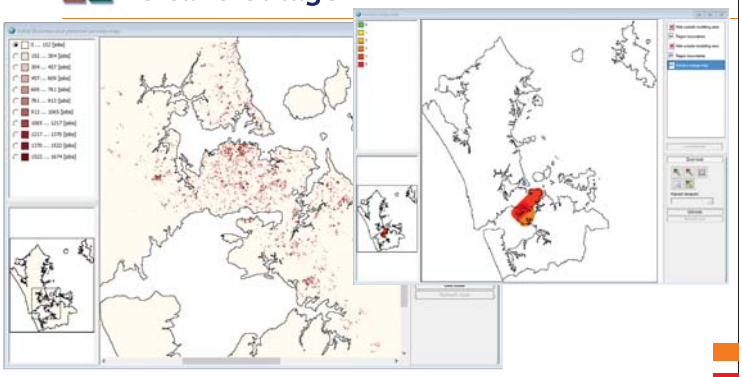
The model in 'shock' mode



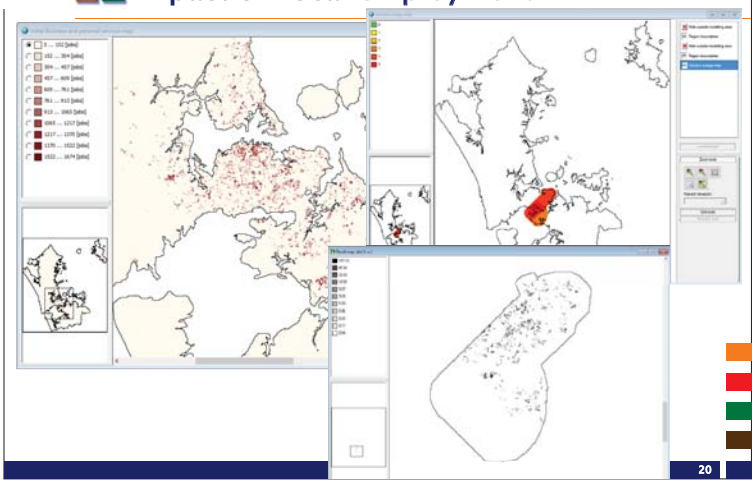
Employment in business and personal services



Volcano outage



Impact on local employment



Conclusions

- **Model integration allows to explore feedback between various processes**
- **Being able to couple models technically doesn't mean the coupling makes sense!**
- **Recommendations for future research**
  - Enhanced calibration and validation
  - Testing on more case studies to assess how generic the approach is
  - Improvements to the simulation run time
  - Enhanced incorporation of interaction of infrastructure outages
  - Incorporation of impacts on population