

NATURAL HAZARD MITIGATION DECISION SUPPORT SYSTEM

Annual project report 2014-2015

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EXECUTIVE SUMMARY

Decision support systems (DSS) that contain integrated models for the assessment of natural hazard mitigation options are an important component for robust, transparent, and long-term mitigation planning. Integrated modelling of underlying social, environmental, and economic systems is required to take into account system dynamics, and to explore the implications of future changes, such as changes in demographics, land use and climate. Consequently, a generic decision support system for the long-term planning of natural disaster impact mitigation options is being developed as part of the Bushfire and Natural Hazards Cooperative Research Centre.

Throughout 2014-2015, the project team has focussed on the production of a framework for the 'development' and 'use' of the DSS. The 'development' aspects propose a generic framework for the integration of models to bridge the science-policy gap through a collaboration between scientists, end users and IT specialists. The 'use' process focusses on the application of the generic DSS to a region of interest; in this project three case study locations are considered including Greater Adelaide, Greater Melbourne and Tasmania. This involves collaboration between modellers, stakeholders and facilitators to customise, calibrate and validate the case-study specific integrated models. Subsequently, the integrated model is used to support a Storyline and Simulation (SAS)[1] approach that attempts to develop scenarios through a participatory process, wherein the DSS helps build and assess these scenarios through an iterative process.

Additional to the production of this overarching framework has been specific model development to ensure appropriate models are available to consider hazard risk within the integrated DSS. Risk models for flooding, coastal inundation and bushfire have been conceptually developed and will be applied to each case study as appropriate. Each model focuses on changing risk spatially and temporally.

The Greater Adelaide DSS is the first case study application of the generic framework, which began with an extensive initial stakeholder engagement phase in September 2014. This involved identification of key stakeholders, questionnaires, interviews and a whole-day workshop at the University of Adelaide on the 18th of September. From there, critical external drivers and uncertainties were identified, along with aspects of risk and indicators of hazard impact and mitigation performance. These factors have subsequently been incorporated within the DSS for Greater Adelaide and a proto-type DSS will be completed in time for further stakeholder engagement around scenario development and DSS use in October/November 2015.

Greater Melbourne and Tasmania have also begun to progress as case studies. Key contacts have been developed in each location, and with the assistance of these contacts, data and model availability have been discussed for each location, along with identification of stakeholders relevant for each location. The first stage of stakeholder engagement for these case studies, as described for Greater Adelaide, will occur in October/November 2015.



END USER STATEMENT

Ed Pikusa, *South Australian Fire and Emergency Services Commission, SA*

The University of Adelaide project has done good work in engaging end users in this project. The scope, research and capability development challenge for this project is considerable, as it requires a great deal of data and a wide variety of stakeholders. University of Adelaide has opted for a structured but highly consultative approach to achieve its aims, which seems with the first case study to be working very well.

The project has gone with the approach of using case studies to demonstrate a potential new capability. In undertaking workshops, they have developed a high level of engagement with the registered end users, as well as subject matter experts relevant to their case studies.

The team is happy to be flexible in scope and deliverables in response to end user issues and concerns, which is a desirable quality in CRC projects. While working to finalise the first case study in Adelaide, they have also been negotiating with stakeholders to commence the second and third in Victoria and Tasmania.

One comment from the recent Research Advisory Forum was to engage more stakeholders from central government agencies. Some progress has been made in engaging an economist from the South Australian Department of Premier and Cabinet as an end user in the latter stages of the Adelaide Case study. This engagement of a central agency stakeholder in the more mature stages of the project is an example that may be useful to replicate in other jurisdictions.

Overall, the University of Adelaide project is delivering what it has promised, and is managing the expectations of its end users.



INTRODUCTION

Disaster mitigation planning is characterised by the need to make decisions in an increasingly complex environment. This complexity comes in a number of forms, including (i) the need to make decisions by selecting from a very large number of options, making it difficult to know which is best, (ii) the need to consider multiple, often competing, objectives during decision-making processes to account for a range of social, economic and environmental criteria, (iii) a lack of clearly-defined, measurable criteria with which to assess the utility of decisions, and (iv) uncertainty in future conditions, data and information.

At the same time, community expectation in relation to the level of protection that can be provided against disasters is increasing. Consequently, there is increased scrutiny of the decisions made in relation to disaster mitigation, necessitating increased transparency in the decision-making process and wise use of limited resources.

However, decision-support tools that enable the above goals to be achieved do not exist at present. Consequently, there is a need to develop a decision support framework that (i) is able to deal with complex problems in a systematic and transparent manner, (ii) makes best use of available sources of data and information, (iii) is adaptable/flexible, (iv) deals with multiple, competing objectives, (v) identifies mitigation options that represent the best possible (optimal) trade-offs between objectives, (vi) deals with uncertainty, (vii) caters to a large number of potential solutions, (viii) enhances understanding of the side effects and impacts of different combinations of policy options and (ix) adopts an interdisciplinary approach across various policy fields.



PROJECT BACKGROUND

DISASTER LOSSES ARE SIGNIFICANT, AND CAN BE REDUCED

The impacts from natural disasters are staggering in regard to human and economic losses. While the immediate and post-crisis response to disasters is extremely important, mitigation activities before a natural disaster occurs can be extremely effective in reducing potential losses — for every dollar spent on mitigation, a saving of one and a half to five dollars in recovery costs can be expected [2]. However, developing and implementing mitigation can be extremely difficult in practice, because of the difficulty of convincing decision makers of the advantages of spending money on mitigation works compared with the short-term benefits offered by other potential projects and activities. In addition, because disasters are relatively infrequent, the people influencing mitigation activities may have little personal experiences to guide their evaluation of risk, or the relative benefits of alternative mitigation options. Furthermore, mitigation budgets are generally limited, and given the difficulties mentioned above, the selection of an optimal set of mitigation options is very difficult when many alternative mitigation options are available.

HOW DECISION SUPPORT SYSTEMS HELP SOLVE THE PROBLEM

Because of these difficulties, the use of decision support systems (DSS) is advantageous, as such systems (1) are transparent and can quantify the expected benefits of mitigation investiture across multiple criteria, enabling strong arguments for the selection of particular mitigation options to be made, (2) can be used to assess the likelihood and consequences of natural disasters across multiple criteria, enabling less bias when assessing the relative benefits of mitigation options, and (3) can make use of formal optimization techniques to find optimal or near-optimal portfolios of mitigation options. However, DSSs for natural disaster mitigation have tended to focus on disaster preparedness and the immediate and post-crisis response to emergencies. Of those DSSs that have focused on mitigation, none have considered, simultaneously, both (1) temporal non-stationarity in climate or land use, and (2) the use of optimization to identify suitable mitigation portfolios. These two aspects are important, as natural disasters are likely to become more frequent with climate change, and because consequences of natural disasters are strongly sensitive to the land uses at the location of the natural disaster.

OUR APPROACH TO BUILDING DECISION SUPPORT SYSTEMS

Consequently, this project will develop an integrated natural hazard mitigation DSS framework, which will be used to develop prototype DDSs for three case studies. Of these three case studies, the first will consider the Greater Adelaide region, the second will likely consider Greater Melbourne and peri-urban fringes, and the third Tasmania. Through a workshop driven development cycle, this project will deliver prototype DSSs to end users that will optimize the choice of mitigation options, through assessing the performance of various options over the long term using simulation-optimisation approaches. The performance of



mitigation options will be evaluated in an integrated way, across a number of natural hazards (bushfire, flooding, coastal surge, earthquake) whilst taking account of land use and climate change.

Consequently, the specific objectives of the project are:

1. To develop a systematic and transparent approach to sifting through, evaluating and ranking disaster and natural hazard mitigation options using analytical processes and tools.
2. To develop prototype decision support software tools that implement the above approach for three end-user defined case studies; Greater Adelaide, Greater Melbourne and peri-urban fringe and Tasmania.

Project Outcomes

The project outcomes will be:

1. Utilisation of a systematic and transparent approach to evaluating disaster and natural hazard mitigation options (e.g. infrastructure, land use, policy).
2. The ability to make more strategic and less responsive decisions in relation to mitigating the impact of disasters and natural hazards as a result of the availability of better information.
3. The availability of prototype decision support software tools for three end-user defined case studies to enable recommended options to be identified by sifting through, evaluating and ranking a large number of options.

Research Questions

Methodological questions the project will help answer, include:

1. What tools are helpful for elucidating mitigation options from domain knowledge experts in workshops (e.g. the use of system diagrams)?
2. How can we compare all mitigation options available, and identify the mitigation options that give the best possible trade-offs between objectives?
3. How might optimisation routines and hazard models be designed to reduce the computational time of finding mitigation options that represent near optimal trade-offs between decision objectives?
4. How significant is the inclusion of landuse change when assessing long term mitigation investment strategies in the three case studies?
5. How can uncertainty be better incorporated within natural hazard mitigation assessment?
6. How can metrics be improved for automated landuse model calibration?



Questions, relating to the case studies, that the project will help answer, include:

1. For each case study, what are the optimal mitigation options across long-term planning horizons?
2. For each case study, how will climate and land use change affect natural hazard risk, and what are the implications for this in regard to disaster mitigation budgets?
3. For each case study, what trade-offs exist between economic, environmental and/or social objectives for different mitigation options?

WHAT THE PROJECT HAS BEEN UP TO

Overall the project has been progressing well on several fronts. The following sections will provide details as to the development of the generic framework for the development and use of the DSS, which was documented in the report titled, *Natural Hazard Mitigation Decision Support System Framework Report, van Delden, Newman [3]*, submitted as deliverable number 2.2.2 on the 6th January 2015. Subsequent sections also provide details on several models developed as part of the integrated model at the the centre of the DSS. Progress is also reported on in regard to the three case studies within the project, with significant progress for the Greater Adelaide case study and Greater Melbourne and Tasmania in their preliminary stages.

DSS DEVELOPMENT & USE FRAMEWORK

The project has developed an iterative framework for the development and use of the DSS (Figure 1). This process is fully documented in van Delden, Newman [3], however, is also described briefly below. The ‘development’ framework is an approach to develop a generic DSS concept that can be applied to each of the case study areas. The ‘use’ process focuses on the aspects required to develop a case specific DSS for each location based on the generic development framework. This is achieved through extensive stakeholder interaction and iteration between the project team and stakeholders throughout the development of the case study DSS; an overview of both the ‘development’ and ‘use’ phases can be seen in Figure 1.

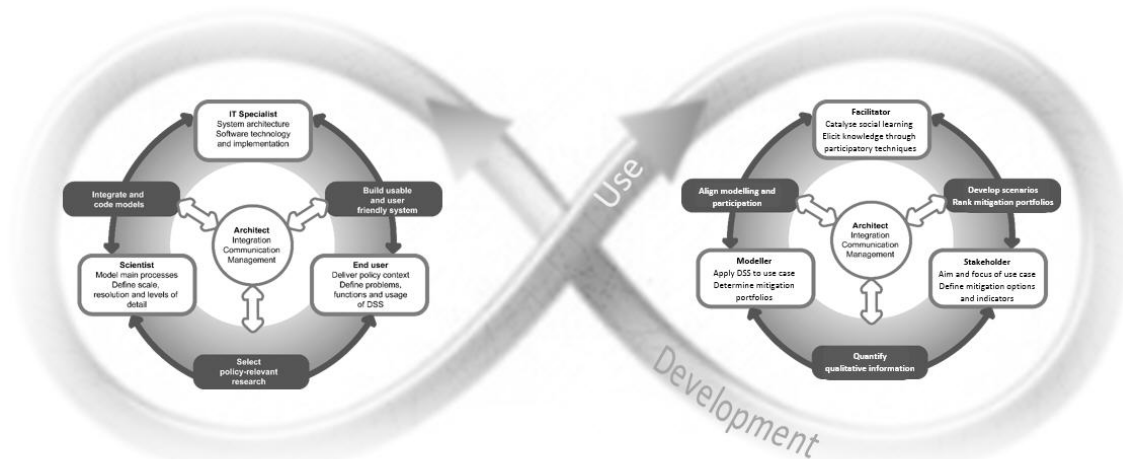


FIGURE 1 DSS DEVELOPMENT AND USE CYCLE

The development process is based on the *Methodology for the Design and Development of Decision Support Systems*, as provided by van Delden, Seppelt [4]. This process involves collaboration between scientists, end users and IT specialists, which is facilitated by a system architect. The tasks in the development process include defining the scope of the planning processes in which the DSS may be used, the selection of models to form a model library within the DSS, the integration of these models into a single modelling platform, bridging



the science-policy gap, and specifying the graphical user interface to the software.

With regard to models, the generic DSS integrates models of the social, natural and built environment with hazard and vulnerability models. These models are needed in order to estimate the values of economic, social, environmental and risk criteria. To understand how these criteria change over the long term, climate, demographic and economic drivers need to be included. Figure 2 shows the modelling components to be included within the integrated simulation model. Externalites are shown in the top blue triangles highlighting external drivers that are influential to future conditions and hence performance of any mitigation options. Mitigation options to be considered are also summarised. Centrally the models highlighted show the combination of social, natural and built environment models included to capture dynamics in vulnerability and exposure, while multiple hazards models can consider the physical process of hazards such as bushfires, floods and earthquakes. The performance of mitigation options on the management of hazard risk will then be judged against a set of indicators such as changes in risk, benefit cost analysis and other social and environmental indicators of performance and impact, as shown in the below green triangle.

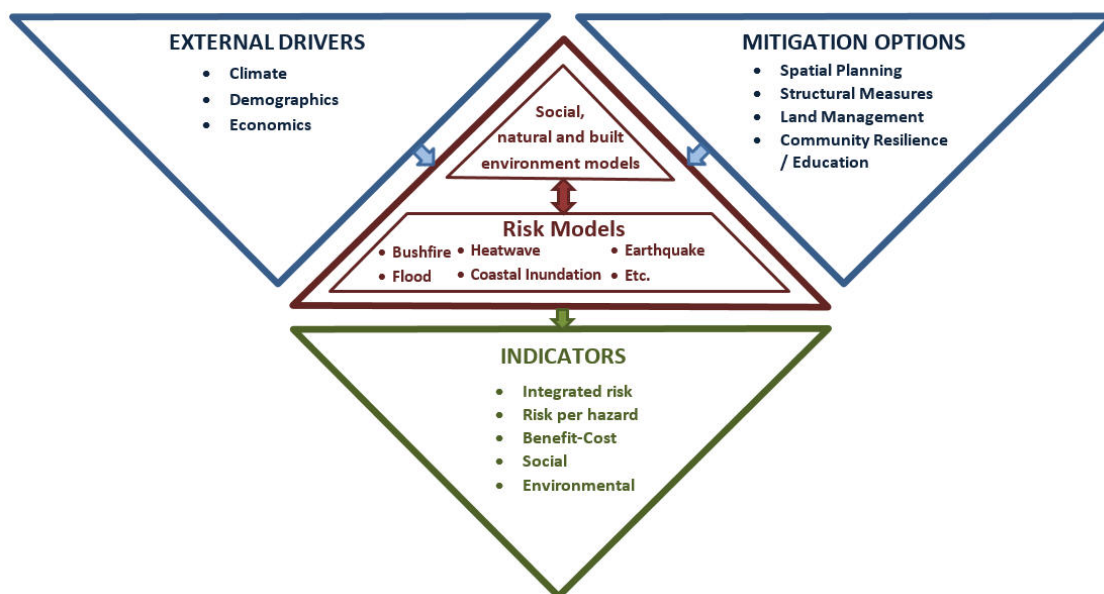


FIGURE 2 MODELLING COMPONENTS FOR INCLUSION WITHIN AN INTEGRATED SIMULATION MODEL THAT IS USED FOR THE ASSESSMENT OF MITIGATION OPTIONS

The use process involves collaboration between modellers and end users in applying the generic DSS to a region of interest. The tasks in the use process include tailoring the generic DSS through selecting models from within the model library, and the calibration and validation of the integrated model. The calibrated model is then used to support a Storyline and Simulation (SAS) approach that attempts to develop scenarios through a participatory process, wherein the DSS helps build and assess these scenarios through an iterative process.



SPECIFIC MODEL DEVELOPMENT

The project team has also developed several hazard risk models to be included within the integrated model system and DSS. This was done as several study locations do not have sufficient or appropriate models to be integrated within the DSS. Details on the developed flood, coastal inundation, and bushfire models can be seen below. Conceptual models for each of these models have been developed and sit within the 'development' phase of the framework and are now being applied to the Greater Adelaide case study.

Flood Inundation Model

A flood hazard model is being developed for the rapid assessment of flooding extent and inundation depth. A simple model of inundation has been chosen to ensure fast computational times. This is critical: given the simulation-optimisation approach being taken by the project, computational expense within the simulation side of the DSS needs to be kept as low as possible due to the computational intensity of the optimisation process.

The flooding model operates by calculating the flow depth along a channel based on historical data. This flow depth is then assigned to raster pixels that correspond to the channel on the output raster. Subsequently, a digital elevation model (DEM) is used to generate the hydrological flow paths across the landscape. The flood depth at a channel raster cell is then propagated through the flow path connected to that cell, assuming a planar water surface, and the flood depth is calculated by subtracting the land surface elevation of a raster pixel (as given by the DEM) from the water surface elevation at that location.

Expected losses are calculated based on Geoscience Australia's Flood Vulnerability Functions for Australian Buildings. These relate losses to inundation depth and construction type (through associated vulnerability curves). Losses are then calculated, using these vulnerability functions and the building stock model for multiple flood events of different return periods. This then allows the creation of a curve for likelihood and impact with risk being represented by the area under the curve (expected losses in any year).

Coastal Inundation Model

A coastal hazard model is being developed for the rapid assessment of flooding extent and inundation depth, given a coastal surge height as input. Conceptually, inundation depth and extent are calculated using a 'bathtub' model. In a similar way to how the flooding model works, the coastal inundation model assumes a planar water surface in determining extent, and calculates inundation depth as the difference between the coastal surge height and the land surface elevation as given from a DEM.

Losses and risk are calculated by the coastal inundation model in exactly the same way as for the flooding model. Based on water depth, construction type (and associated vulnerability curves), and economic value regarding values at risk in a region, expected losses can be determined for the particular coastal inundation event. This then allows the creation of a curve for likelihood and



impact across multiple representative events, with risk being given by the area under the curve.

Bushfire Risk Model

A bushfire risk model is being developed by adapting the TASBRAM application developed by David Taylor at Tasmania Parks & Wildlife and InsightGIS, see InsightGIS [5] This model considers the likelihood of bushfire events in a particular cell based on three main components, including ignition potential, fire behaviour and suppression capability. Ignition potential is combination of factors relating to lightning probability (based on historical data and can be influenced by climate change) and historical data regarding man lit fires. Fire behaviour consists of head fire intensity, a function of fuel groups and weather data (90th weather percentile) and the rate of spread (an existing model based on fuel groups and weather), along with vegetation type and slope. Suppression capabilities relate to how quickly a fire can be detected and suppressed and is determined by the number of fire stations, fire towers, roads and air support/attack that are available. These factors are combined spatially to determine the likelihood of occurrence of a bushfire in each cell. Economic data is then overlaid to assess number of people and capital stock at risk for each cell. This model is currently in development for the Greater Adelaide case study with the generic framework to be applied to all three case studies considered.

DSS CASE STUDIES

Three case studies are included in the DSS project to allow the application of the generic development framework across distinct geographic areas. Specific DSS applications are developed for each case study to incorporate alternate hazards, drivers and indicators through consultation with key stakeholders within mitigation planning for each location. The following sections provide details as to the progress for each case study location: Greater Adelaide, Greater Melbourne and Tasmania.

Greater Adelaide DSS

The Greater Adelaide DSS project began in earnest with an initial stage of stakeholder engagement in September 2014, which was preceded by extensive data collection for critical model components. The initial stakeholder engagement consisted of the development of a list of relevant stakeholders; this was done between lead end user Mr Ed Pikusa (SAFECOM) and members of the project team. Stakeholders were mostly members of the State Mitigation Advisory Group (SMAG), but supplemented with some NGOs and other government departments.

All identified stakeholders were invited to complete questionnaires covering topics such as key drivers in South Australia's ability to mitigate natural hazards, key uncertainties that could affect SA's ability to mitigate natural hazards, along with governance focused questions on the participants organisation's decision making role and strategies for dealing with planning decisions. These questionnaires were then followed up by interviews with the stakeholders and two members of the project team. The aims of these interviews were to begin

developing relationships between the project team and stakeholders, clarify responses to the questionnaire and offer more information on the project as a whole.

A full day workshop was held at the University of Adelaide on the 18th September 2014. The workshop consisted of presentations regarding the development of the DSS, along with presenting results from the questionnaires and interviews. Breakout sessions were then facilitated to gain details on stakeholder views on possible mitigation options, aspects of risk to be considered for each hazard, and performance/impact indicators for mitigation options. Discussion of the use of the DSS was also included in a session which led to discussions of governance within SA on hazard mitigation planning. Full details of this initial stakeholder engagement phase can be seen in Van Delden, Riddell [6]

Following from this workshop, development of the Greater Adelaide DSS has progressed. The central land use model is in calibration phase based on three sets of South Australian land use data (2001, 2006, 2011). The bushfire and flooding models are also being developed for the case study area and will be integrated into the DSS in the coming months. Three earthquake scenarios are also being developed for Greater Adelaide, which will be included within the DSS. A system diagram for the proposed DSS is shown in Figure 3. All model development and integration will be completed prior to the second stage of stakeholder engagement planned for October 2015.

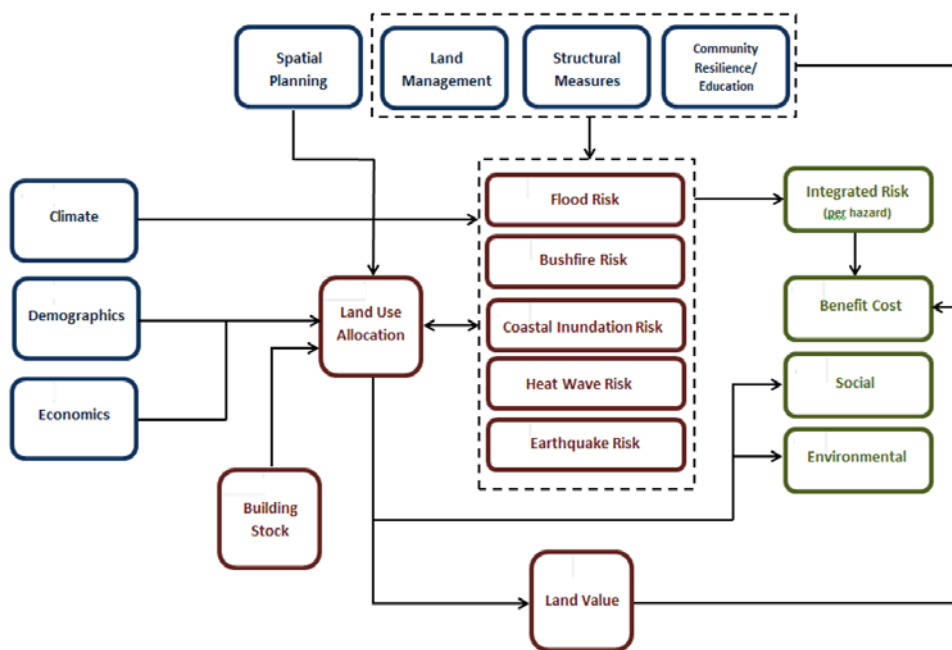


FIGURE 3 GREATER ADELAIDE INTEGRATED MODEL SYSTEM DIAGRAM

Greater Melbourne & peri-urban fringe DSS

Following on from several meetings with Alen Slipjevic (Vic CFS), Joe Buffone (EMV) and Liam Fogarty (DEPI), the development of a case study centered on Greater Melbourne and extending into peri-urban regions is also progressing. This case study is beginning to be formulated, with stakeholders in Victoria currently being identified between the project team and key stakeholders, as previously



mentioned. Once this list is finalised, the initial stage of stakeholder engagement, as documented above for Greater Adelaide, is planned for October/November 2015. With this, DSS development can proceed following the DSS use framework.

Tasmania DSS

The case study for Tasmania is at a similar stage as Greater Melbourne, with Luke Roberts (Tas DPC) as the key contact for the state. Conversations have been focused on available data and models for Tasmania in terms of hazard risk and mitigation planning. Interactions have also focused on the identification of stakeholders in Tasmania for the first stage of stakeholder engagements planned for October/November 2015.

CONFERENCE ATTENDANCES

Several conferences have been attended and presented at by project members over the past 12 month period.

Jeffrey Newman presented at AFAC 2014, in Wellington, New Zealand. This conference was also attended by Holger Maier, Hedwig van Delden, Graeme Riddell and Charles Newland.

Charles Newland presented at the Urban Modelling conference in Lyon, France in October 2014. He has also presented his research at GeoComputation 2015 in Dallas, Texas, USA. Details of these presentations can be found below in Conference Presentations.

Hedwig van Delden, Graeme Riddell and Michael O’Flaherty also attended the Society for Risk Analysis Europe Annual Meeting in Maastricht, the Netherlands in June 2015. Both Hedwig and Graeme presented various aspects of the DSS project and it was well received. Details of the presentations can again be found below in Conference Presentations.

INTERNATIONAL COLLABORATIONS

A relationship with Karlsruhe Institute of Technology’s Centre for Disaster Management and Risk Reduction Technology (CEDIM) has been developed. Experts on geological hazards from CEDIM have provided input into earthquake scenario development for Greater Adelaide along with comments on our proposed framework for risk mitigation planning. We look forward to continued collaboration with this group in terms of knowledge sharing and possible future joint publications.

The University of Adelaide’s School of Civil, Environmental & Mining Engineering, through the DSS project, were invited to be members of the Stakeholder Advisory Group for the European CIRCLE (A panEuropean framework for strengthening Critical Infrastructure resilience to climate change) project. The project looks to analyse and subsequently develop resilience in critical infrastructure networks across the EU to climate change and its impacts. Graeme Riddell attended the project’s kick-off meeting in Athens on the 9th & 10th of June 2015. Members of the DSS project will subsequently be invited to offer comment on the CIRCLE



framework and exchange knowledge throughout the duration of the respective projects.



PUBLICATIONS LIST

REPORTS

Hedwig van Delden, Jeffrey P. Newman, Graeme A. Riddell, Holger R. Maier, Aaron C. Zecchin, Graeme C. Dandy (January 2015) "Natural Hazard Mitigation Decision Support System Framework Report" The University of Adelaide, Bushfire & Natural Hazard Cooperative Research Centre.

Hedwig van Delden, Graeme A. Riddell, Ariella Helfgott, Jeffrey P. Newman, Holger R. Maier, Charles P. Newland, Aaron C. Zecchin, Graeme C. Dandy (December 2014) "Greater Adelaide DSS Stakeholder Engagement Stage 1 Report" The University of Adelaide, The Bushfire & Natural Hazard Cooperative Research Centre.

Jeffrey P. Newman, Holger R. Maier, Hedwig van Delden, Aaron C. Zecchin, Graeme C. Dandy, Graeme R. Riddell, Charles P. Newman (August 2014) "Literature Review on Decision Support Systems for Optimising Long-Term Natural Hazard Mitigation Policy and Project Portfolios" The University of Adelaide, The Bushfire & Natural Hazard Cooperative Research Centre.

CONFERENCE PAPERS

Charles P. Newland, Hedwig van Delden, Holger R. Maier, Jeffrey P. Newman, and Aaron C. Zecchin (July 2015) "Relationships between Cellular Automata based land use models parameters and spatial metrics: Enhancing understanding in a calibration context" Computers in Urban Planning and Urban Management 2015, Cambridge, MA, USA.

Jeffrey P. Newman, Holger R. Maier, Hedwig van Delden, Aaron C. Zecchin, Graeme C. Dandy, E. Pikusa (September 2014) "Integrated disaster decision support system incorporating mitigation portfolio optimisation" Research Forum at the Bushfire and Natural Hazards CRC & AFAC conference, Wellington, NZ.

CONFERENCE PRESENTATIONS

J. P. Newman, H. van Delden, H. R. Maier, G. C. Dandy, A. C. Zecchin and E. Pikusa (September 2014) "Integrated disaster decision support system incorporating mitigation portfolio optimisation" AFAC 2014 Conference, Wellington, New Zealand.

Charles P. Newland, Hedwig van Delden, Jeffrey P. Newman, Holger R. Maier and Aaron C. Zecchin (October 2014) "Enhanced understanding of Cellular Automata land use models by sensitivity analysis of key parameters" Urban Modelling – Toward Integrated Modelling of Urban Systems Conference, Lyon, France.

Charles P. Newland, Hedwig van Delden, Holger R. Maier, Jeffrey P. Newman, Michael O'Flaherty, Roel Vanhout, and Aaron C. Zecchin (May 2015) "A utility study of Any Colony Optimization for automated calibration of land use Cellular Automata models" GeoComputation 2015, Dallas, Texas, USA



Graeme A. Riddell, Hedwig van Delden, Aaron C. Zecchin and Holger R. Maier (June 2015) "Applying 'outcomes of interest' scenario framework to consider uncertainties impacting risk reduction policies" Society for Risk Analysis Europe Annual Meeting, Maastricht, the Netherlands.





Hedwig van Delden, Graeme A. Riddell, Jeffrey P. Newman Aaron C. Zecchin, Holger R. Maier, Roel Vanhout and Graeme C. Dandy (June 2015) "Integrating approaches to support multi-hazard mitigation planning" Society for Risk Analysis Europe Annual Meeting, Maastricht, the Netherlands.



CURRENT TEAM MEMBERS

	<p>Prof. Holger Maier (University of Adelaide)</p> <p>Project Lead Researcher, responsible for ensuring that the project delivers to contractually agreed scope and budget, and also responsible for the project communication between end-users and the project team, and communication with the cluster Lead User Representative and Lead Researcher. Also responsible for supervision of post-doctoral fellow and PhD students.</p>
	<p>Dr Aaron Zecchin (University of Adelaide)</p> <p>Deputy project leader, co-supervision of post-doctoral fellow and PhD students, oversight of optimisation and development of overall process and decision support system.</p>
	<p>A/Prof Hedwig van Delden (Research Institute for Knowledge Systems (RIKS) / University of Adelaide)</p> <p>Key researcher, responsible for running participatory workshops with end-users, data/information/model integration, application and calibration of the Metronamica land use modelling framework for those cases it will be applied to, and development of DSS software. Also responsible for supervision of post-doctoral fellow and PhD students. Accountable to the Project Lead Researcher for delivery of the prototype DSSs.</p>
	<p>Emeritus Prof Graeme Dandy (University of Adelaide)</p> <p>High level oversight on optimisation and development of overall process.</p>
	<p>Dr Ariella Helfgott (University of Adelaide / University of Wageningen / Oxford University)</p> <p>Assistance with running participatory workshops.</p>



	<p>Jeffrey Newman (University of Adelaide)</p> <p>Responsible for literature review, collection of available data, information and models, development of overall framework, development and implementation of optimisation component of the project, day-to-day running of the project.</p>
	<p>Graeme Riddell (University of Adelaide)</p> <p>Graeme’s PhD project looks to develop a framework to handle <i>knowledge uncertainty</i> (an uncertain future state of the world) for decision making with a focus on natural hazard mitigation planning.</p>
	<p>Charles Newland (University of Adelaide)</p> <p>Spatially distributed models are an effective means for the assessment of policy and planning investment options for optimal natural hazard mitigation. To broaden the applicability of spatially distributed models and allow more effective and efficient usage by decision makers, Charles’ research aims to improve their calibration procedure.</p>
	<p>Michael O’Flaherty (University of Adelaide)</p> <p>Michael’s research will investigate the impact of risk-perception on patterns of land-use change and land prices. Using an agent-based modeling approach, Michael will examine the decision making process at the individual level with a particular focus on model calibration and validation.</p>



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