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MULTI-HAZARD MITIGATION PLANNING, COMBINING MODELLING, SCENARIOS AND OPTIMISATION: RESULTS FROM SOUTH AUSTRALIA

Non-peer reviewed research proceedings from the Bushfire and Natural Hazards CRC & AFAC conference
Sydney, 4 – 6 September 2017

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Version	Release history	Date
1.0	Initial release of document	04/09/2017

Publisher:
Bushfire and Natural Hazards CRC

September 2017

Citation: Riddell, G. A., van Delden, H., Vanhout, R., Maier, H. R., Newman, J. P., Zecchin, A. C. & Dandy, G. C. (2017) Multi-hazard mitigation planning, combining modelling, scenarios and optimisation: results from South Australia. In M. Rumsewicz (Ed.), *Research Forum 2017: proceedings from the Research Forum at the Bushfire and Natural Hazards CRC & AFAC Conference*. Melbourne: Bushfire and Natural Hazards CRC.

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EXTENDED ABSTRACT

Natural hazards are an unavoidable component of life in Australia, but with effective planning and mitigation spending, their impacts can be minimised significantly. Analysis shows an average cost of natural hazards in Australia for 2015 totalled $9.6 billion, and this figure is projected to increase to $33 billion by 2050 (Deloitte Access Economics, 2016). These figures correspond to a substantial impact and coupled with the social and environmental impacts of disasters, paint a bleak picture. However, tomorrow's risk is a function of decisions made today, including the developments permitted and laws passed, and as such there is significant scope to minimise tomorrow's impacts.

To assist in the understanding of tomorrow's risk, driven by changing hazards, exposure and vulnerability, a decision support system (DSS) and integrated use process have been developed. This DSS models risk into the future and how it is driven by climatic, economic and demographic factors. Figure 1 shows the integration of risk across exposure, vulnerability and hazard along with some of the factors that are encompassed, as well as the drivers and uncertainties surrounding these factors that make the future so hard to predict.

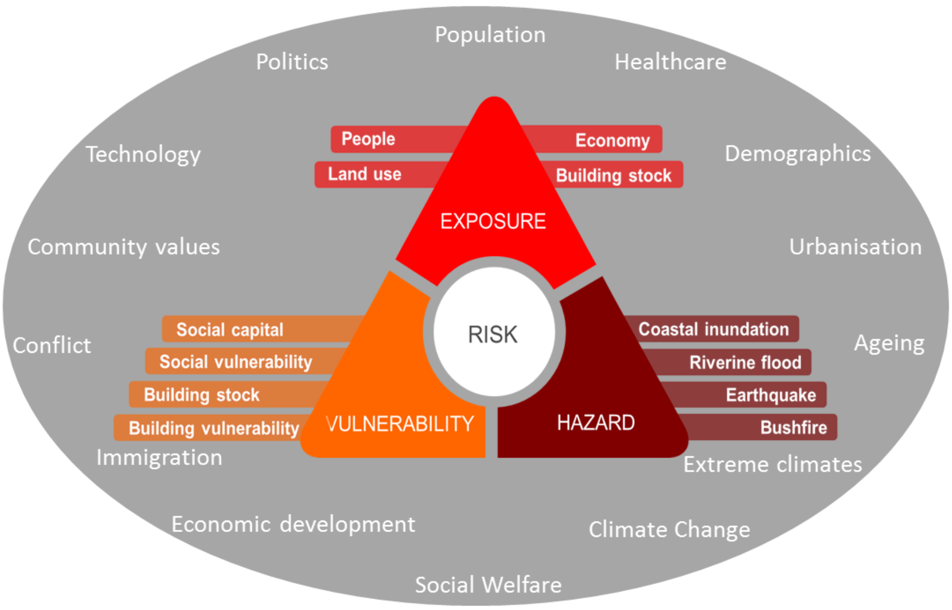

FIGURE 1 - FACTORS, DRIVERS AND UNCERTAINTIES OF RISK

The DSS was developed for Greater Adelaide, South Australia (SA), through an iterative, stakeholder-focussed process to ensure the system was capable of providing the analysis required by policy and planning professionals in the emergency management field. The process involved a series of interviews and workshops with members of the South Australian Government, aligning risk reductions to be included, policy relevant indicators and future uncertainties, such that the system can sit within existing policy processes. The overarching system diagram of the DSS is shown in Figure 2, and consists of drivers, modelled processes, risk reduction options and indicators (currently only risk metrics, but this is to be modified to consider broader socio-economic-environmental factors).

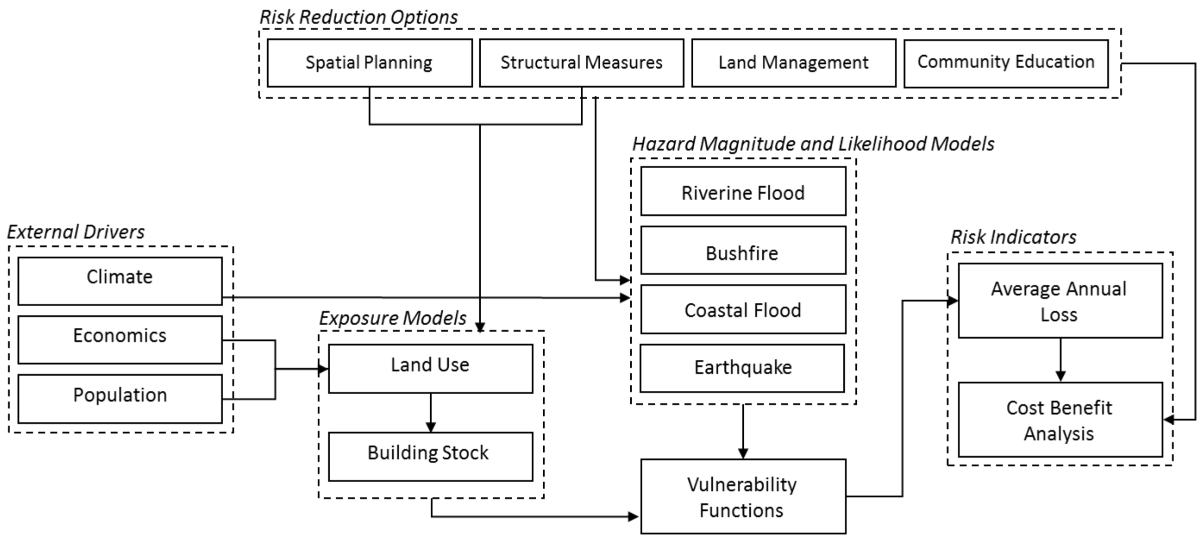

FIGURE 2 - SYSTEM DIAGRAM FOR DSS FOR GREATER ADELAIDE, SA

Within the DSS, exposure is considered dynamically with the inclusion of a land use allocation model (RIKS, 2015) and building stock information retrieved from the NEXIS database (Dunford et al., 2015). The land use allocation model operates on a square grid of 100m cells. The model is the cellular automaton (CA) based Metronamica model which calculates the state of each cell within the overall growth of the region of interest (Greater Adelaide for this study), driven by population and economic demands (White and Engelen, 1993; RIKS, 2015).

A suite of hazard models is also included, as shown in Figure 2. For bushfire, coastal inundation, riverine flood and earthquake, average annual direct loss is calculated using appropriate processes and input data to capture the nature of the hazard. For example, bushfire hazard likelihood and intensity is considered using three factors; ignition potential (a function of land use, road proximity and vegetation), suppression capability (the probability of first wave attack success), and fire behaviour (a function of climate, slope and fuel load). Hydro-meteorological hazards are considered using a digital elevation model and inundation depths for various return periods and future climate scenarios. Earthquake hazard is calculated by a using a probabilistic set of 100 events calibrated on historical earthquake events in the region. For each of these hazards, direct losses are considered by taking the magnitude outputted from the hazard models and converted using vulnerability curves for the building stock dependent on its construction type. By using these curves, for specific hazards and construction types, relative damage indices can be multiplied by the building stock's value, providing an output of direct monetary loss.

Risk reduction options are considered across hazard, exposure and vulnerability. For hydro-meteorological hazards, structural measures such as levies and sea walls can be implemented to alter flow and inundation paths, whereas vegetation management (planned burns) can be used to influence fuel loads in the calculation of bushfire intensity. Spatial planning measures can also be implemented, reducing exposure to all hazards. In addition, changes to building codes and retrofitting can be considered by altering the vulnerability curves that relate hazard magnitude to damage. The impact of these risk reduction options I s shown through the calculation of average annual loss for baseline conditions with no risk reduction versus the average annual loss after an option has been implemented. The difference between these two scenarios is used in the cost benefit analysis of various risk reduction options.

Within the integrated participatory use process for the DSS, scenarios for Greater Adelaide's development were also developed. The purpose of these scenarios was to begin to handle the complexities and uncertainties that impact on natural hazard risk reduction planning by capturing them within internally consistent, plausible explanations of how events unfold with time (Raskin et al., 2002). Five scenarios were developed considering how the Greater Adelaide region progresses to be either more or less socially resilient, or more or less open to government implementation of mitigation options. The qualitative aspects of the scenarios are summarised in Table 1 via their motivating factors. The scenarios were also translated to quantitative model parameters and modelled to provide five different perspectives on the region's development, future land use and associated risk profiles across each of the four hazards included within the DSS.

TABLE 1- SCENARIOS FOR GREATER ADELAIDE, MOTIVATING FACTORS

Scenario	Motivating Factor
Silicon Hills *Low challenges to resilience and mitigation*	Growing valuation of nature and stimulation of tech industries see increase in skills for technology, innovation and R&D.
Cynical Villagers *High challenges to mitigation*	Downturn in mining and ageing population, shift towards nature and high quality agricultural society.
Ignorance of the Lambs *High challenges to resilience*	Large immigration to SA from various global areas of unrest. Increasing reliance on Federal Government for funding.
Appetite for Change *Moderate challenges to resilience and mitigation*	Current projections hold steady, however mid-scenario a series of hazard events leads to increased community awareness.
Internet of Risk *High challenges to resilience and mitigation*	Increasing reliance on the internet for social and work-related activities decreases community connectedness and resilience.

The scenarios propose various futures for Greater Adelaide that are all considered relevant and plausible by stakeholders involved in the development and use process of system. The scenarios, once modelled using the spatially-explicit simulation model, can be applied to assess mitigation options and portfolios. Options and portfolios can be tested across them to consider which options are most effective under different conditions or robust for a variety of future conditions (Maier et al., 2016).

The development of portfolios for each scenario is performed by multi-objective evolutionary algorithm optimisation. This optimisation searches the solution space, different mitigation options implemented at different times and locations, to assess which are the most effective in terms of risk reduction (reducing average annual loss) and cost (cost of designing, implementing and maintaining any option). The mitigation portfolios, and visualisations of how they perform with regard to the indicators, is then fed back to the stakeholder group to allow improvement of the exploratory storylines. There is the allowance for fine-tuning of scenario drivers, mitigation options and indicators. This process should be iterative, and stakeholders should be involved throughout the process, as this is critical in achieving effective scenarios.

The combination of developing the DSS with stakeholder perspectives throughout, coupled with scenarios and the optimisation of mitigation options, presents a novel way for considering the challenges, and complexity of long term risk reduction planning. A participatory approach is critical in considering the vast degree of ambiguity and uncertainty around long term planning. This, coupled with quantitative assessment via simulation modelling and optimisation, offers a method for transparent and robust decision making. The process also enables the development of strategic capacity in understanding and subsequently managing the drivers of risk into the future. Further work will look to improve the modelling processes along with the implementation of the system within existing policy processes.

REFERENCES

Deloitte Access Economics, 2016. The economic cost of the social impact of natural disasters. Australian Business Roundtable for Disaster Resilience and Safer Communities: Kingston, ACT.

Dunford, M. A., Power, L., Cook, B., 2015. National Exposure Information System (NEXIS) Building Exposure – Local Government Area (LGA). Commonwealth of Australia (Geoscience Australia).

Maier, H.R., Guillaume, J.H.A., van Delden, H., Riddell, G.A., Haasnoot, M., Kwakkel, J.H., 2016. An uncertain future, deep uncertainty, scenarios, robustness and adaptation: How do they fit together? Environmental Modelling and Software 81 154-164.

Raskin, P., Banuri, T., Gallopin, G., Gutman, P., Hammond, A., Kates, R., Swart, R., 2002. Great Transition: The promise and lure of the times ahead, Tellus Institute. Global Scenario Group, Stockholm Environment Institute: Boston.

RIKS, 2015. Metronamica-Model descriptions, (available on http://www.metronamica.nl). RIKS: Maastricht.

White, R., Engelen, G., 1993. Cellular Automata and Fractal Urban Form: A Cellular Modelling Approach to the Evolution of Urban Land-Use Patterns. Environment and Planning A 25(8) 1175-1199.