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IMPROVED DECISION SUPPORT FOR NATURAL HAZARD RISK REDUCTION

Annual project report 2018-2019

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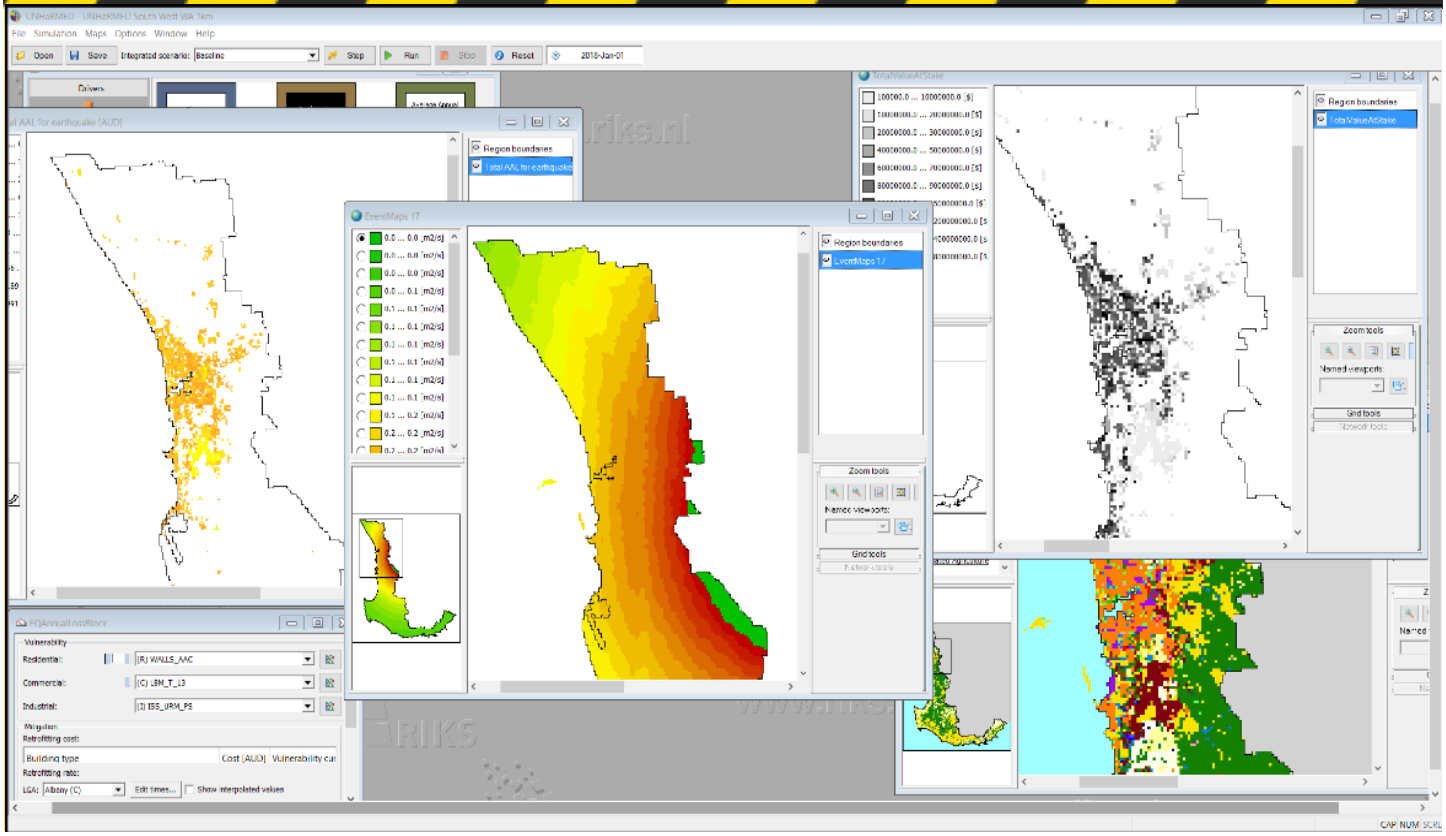

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RIKS research institute for knowledge systems

Version	Release history	Date
1.0	Initial release of document	30/06/2020

Publisher:
Bushfire and Natural Hazards CRC

June 2020

Citation: Maier H, Riddell G, van Delden H, Araya S, Zecchin A, Vanhout R, Dandy G & Hamers E (2020) Improved decision support for natural hazard risk reduction – annual project report 2018-2019, Bushfire and Natural Hazards CRC, Melbourne.

Cover: UNHaRMED software. Source: University of Adelaide.

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ACKNOWLEDGMENTS

The research team at the University of Adelaide and the Research Institute for Knowledge Systems would like to thank all our end-users across South Australia, Victoria, Tasmania and Western Australia, along with all participants and stakeholders who have been involved with this project through workshops, interviews and many meeting; your insight and contributions were invaluable.

We would also like to thank everyone within the Bushfire and Natural Hazards CRC office who have supported this work in multiple ways from funding, contracting and business development.

EXECUTIVE SUMMARY

There is increasing recognition of the urgency to consider how disaster risk might change into the future, what impacts this is likely to have and, most importantly, what we can do to reduce this risk. There is also increased recognition that in order to achieve this, we need to adopt a holistic approach that takes into account community values, vulnerabilities and resilience, future changes in population and demographics, climate change, multiple hazards, cascading events, adaptation and a range of risk reduction strategies, such as land use planning, community education, land management, structural measures and changes to building codes.

Over the last five years, this project has co-developed conceptual, modelling and decision support frameworks for tackling the above problems in conjunction with more than 40 end-user organisations in four states (South Australia, Western Australia, Tasmania and Victoria). The frameworks facilitate:

- the development of the capacity for strategic thinking and for tackling long term disaster risk in an integrated fashion
- the collaboration between different government departments and different levels of government (federal, state and local)
- the development of a shared understanding of risks and values between a range of stakeholders (e.g. different levels of government and the community)
- the quantification of how disaster risks and costs might change into the future under a range of integrated socio-economic and climate scenarios
- the development of the best adaptive mitigation strategies under these scenarios.

The above frameworks have resulted in the development of the decision support software UNHaRMED (Unified Natural Hazards Risk Mitigation Exploratory Decision support system), applications for which have been co-developed with end-users for greater Adelaide, Perth and surrounds, Tasmania and greater and peri-urban Melbourne. In Adelaide, UNHaRMED is being used in collaboration with local governments for strategic flood mitigation planning and the development of a state emergency management exercise focused on recovery and long term mitigation related to sea level rise.

End-user training for the Perth and Tasmania UNHaRMED applications only occurred in 2019 and relevant agencies in these states are working towards the incorporation of these applications in state planning processes. End-user training for the greater and peri-urban application of UNHaRMED will take place in July 2019.

Other opportunities have also presented themselves in working with agencies and providing outputs and insight from UNHaRMED into other projects and products. These have included working with the SA Government on a mitigation exercise which will take place early in the next financial year focused on how to explore future impacts of coastal flooding and develop mitigation activities to

be implemented. Another has been working with the National Resilience Taskforce on modelling capabilities for understanding climate and disaster risks.

END-USER PROJECT IMPACT STATEMENT

Ed Pikusa, *Department for Environment and Water, SA*

This project has continued to grow and develop interest across a large spectrum of end-users, both within and outside of the CRC. The research team continues to show its willingness to engage with and adapt the UNHaRMED platform to a wide variety of stakeholders.

The power of UNHaRMED is its versatility, and the ability of it to be applied to almost any mitigation issues that can be expressed geographically.

The case studies, and most recently, application of UNHaRMED to a 'mitigation exercise', have been chosen as a means to apply the model in ways that can be relevant to end-users.

The mitigation exercise, conducted over two workshops in August/September 2019, illustrates the potential of UNHaRMED to model impacts from future disasters and guide decision making for mitigation options to avert future losses.

It is hoped that this and other applications of the platform across the country can either be applied directly by end-users or illustrate enough of its potential to allow end-users to scope a new application.

This platform, working with other projects to integrate their data and modelling, goes from strength to strength each year.

INTRODUCTION

The challenges facing policy makers grow increasingly complex and uncertain as more factors that impact on their ability to manage the environment and its risks need to be considered. Due to a large number of influencing environmental and anthropogenic factors, natural hazard risk is difficult to estimate accurately, and is exaggerated by large uncertainty in future socio-economic consequences. Furthermore, resources are scarce, and the benefits of risk reduction strategies are often intangible.

Consequently, this project looks to develop various processes and software applications to assist managers with better understanding disaster risk, which offer significant advantages with regard to strategic policy assessment and development.

The key output of the project is the software application UNHaRMED. This system allows for the dynamic understanding and assessment of all three components of risk; exposure, vulnerability and hazard, in line with recent recommendations from the World Bank's Global Facility for Disaster Reduction and Recovery (Fraser et al., 2016). UNHaRMED thus allows policy makers to better understand the drivers of risk and the impact of their policies on risk profiles now and into the future. This enables policy makers to account for climate change, urbanisation, population increases and future environmental conditions in risk assessments.

Accompanying the system is a framework that facilitates its development and supports its uses by organisations such that it:

- is able to deal with complex problems in a systematic and transparent manner
- makes the best use of available sources of data and information
- is adaptable/flexible
- deals with multiple, competing objectives
- identifies mitigation options that represent the best possible (optimal) trade-offs between objectives
- deals with uncertainty
- caters to a large number of potential solutions
- enhances understanding of the side effects and impacts of different combinations of policy options
- adopts an interdisciplinary approach across various policy fields.

This report provides information on the various elements of this project including:

- research approach for the development of UNHaRMED and supporting frameworks
- key milestones in the development and application of the research across different jurisdictions in Australia
- summary of utilisation and impact across jurisdictions and applications of UNHaRMED.

BACKGROUND

DISASTER LOSSES ARE SIGNIFICANT AND CAN BE REDUCED

The impacts from disasters are significant in terms of human and economic losses. While the immediate and post-crisis response to disasters is extremely important, mitigation activities before a 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 (Rose et al., 2007).

However, developing and implementing mitigation can be extremely difficult in practice, in part, 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 a set of mitigation options is very difficult when many alternative options are available.

HOW UNHARMED CAN HELP SOLVE THE PROBLEM

Because of these difficulties, the use of decision support systems (DSS), in the case of this project the developed DSS – UNHaRMED – is advantageous, as such systems:

- 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
- can be used to assess the likelihood and consequences of disasters across multiple criteria, resulting in less bias when assessing the relative benefits of mitigation options
- can make use of formal decision science techniques to find portfolios of mitigation options most effective under a range of conditions.

However, DSSs for disaster risk reduction have tended to focus on disaster preparedness and the immediate and post-crisis response ot emergencies. Of those DSSs that have focused on mitigation, none have considered dynamics and drivers across the three components of disaster risk—hazard, exposure and vulnerability, or the integrated assessment of a range of risk reduction options, both structural and non-structural.

RESEARCH APPROACH

The research approach developed to enable the required outcomes is broken into several streams to enable prototype software applications to be developed with users and tested by them in shorter time periods taking a co-creation approach.

The following sections outline the key frameworks developed to support the research approach, including:

- co-creation to support strategic disaster risk management through developing a generic approach for the development and use of a decision support system for risk reduction planning
- how this has resulted in the software application UNHaRMED and been implemented across different regions in Australia
- how extensions to the framework are being developed to enable a more sophisticated understanding of societal elements of risk.

CO-CREATION FOR DEVELOPING AND USING DECISION SUPPORT SYSTEMS FOR DISASTER RISK MANAGEMENT

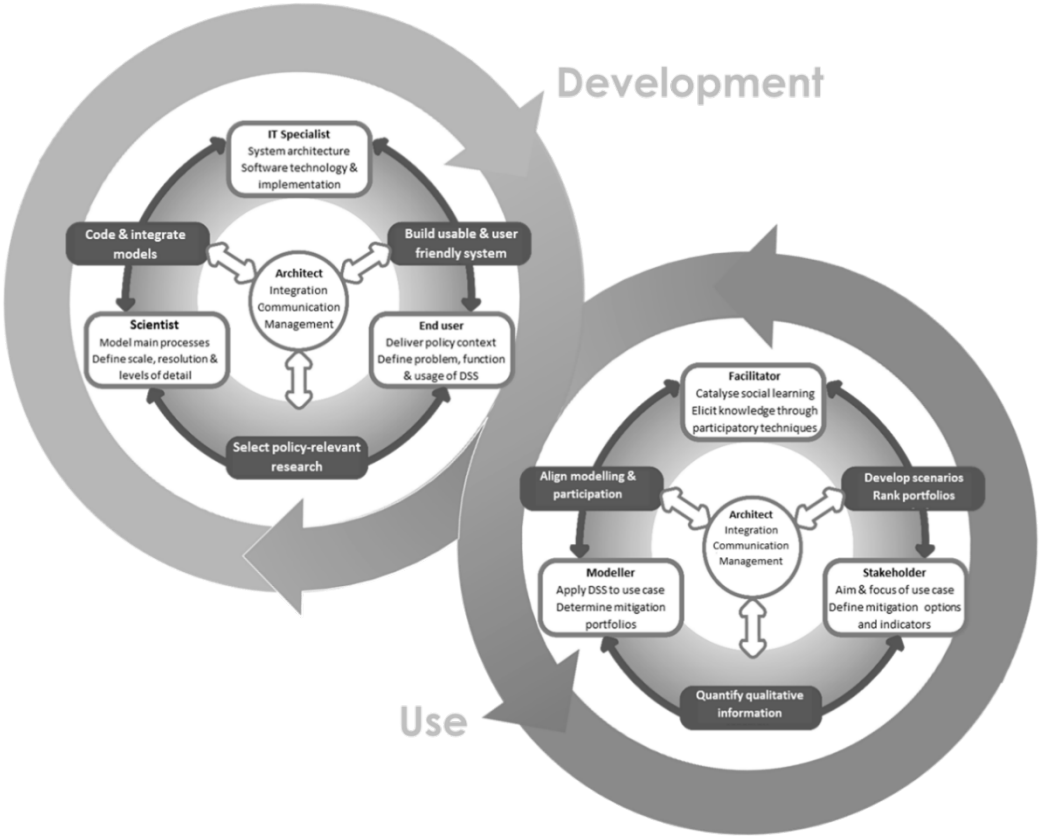
The project has developed and tested an approach to developing generic disaster risk management (DRM) DSSs that enables the dynamic assessment of future risk and risk reduction options and maximises their use potential the approach is underpinned by separate but linked processes for development and use based on the principles of co-creation. This involves various end-users, stakeholders, scientists, modellers, IT specialists and facilitators throughout the entire process. Co-creation enables the DSS to be jointly developed and used by the actors involved in the processes, allowing the outcomes to be owned by all involved.

The main aim of the development process is to deliver a generic DSS that provides support for DRM and is sufficiently generic and flexible to be customised and applied to various regions/jurisdictions and policy/investment contexts. Such a generic DSS incorporates an integrated simulation model with a model library consisting of spatially-explicit and dynamic model components for hazard, exposure, vulnerability and risk, exposed through a user-friendly and intuitive graphical user interface.

As part of the use process, the generic DSS is tailored to the region and questions of interest. The main aim of the use process is to provide support to the DRM process by analysing how risk changes over time and in space, how risk reduction portfolios (groups of risk reduction options) impact on risk, what the wider consequences of those options are, and where win-win situations can be created or trade-offs are required. The use process focuses on how to best provide this support with information the DSS can provide—but is not limited to the information the DSS provides—and emphasises the importance of connecting modelling with relevant policy contexts and processes.

Figure 1 provides an illustration of the approach, with the development process shown on the left-hand side and the use process on the right-hand side. As mentioned previously, this iterative approach focuses on the co-creation of:

- a generic DSS that incorporates an integrated multi-hazard modelling framework
- case specific support to disaster risk management by developing a case specific software application and embedding this in a process for assessing risk and risk reduction options.



Further details of the approach are documented in:

- van Delden H, Riddell GA, Maier HR, Newman JP, Zecchin AC & Dandy GC (2018) UNHaRMED – Framework for the development and use of decision support systems for disaster risk management through co-creation, Bushfire and Natural Hazards CRC, Melbourne.
- van Delden H, Riddell GA, Maier HR, Newman JP, Zecchin AC, Dandy GC & Vanhout R, Co-creation to support strategic disaster risk management: a generic approach for the development and use of a decision support system for risk reduction planning, *Socio-Environmental Systems Modelling*, (invited paper – submitted).

UNHARMED

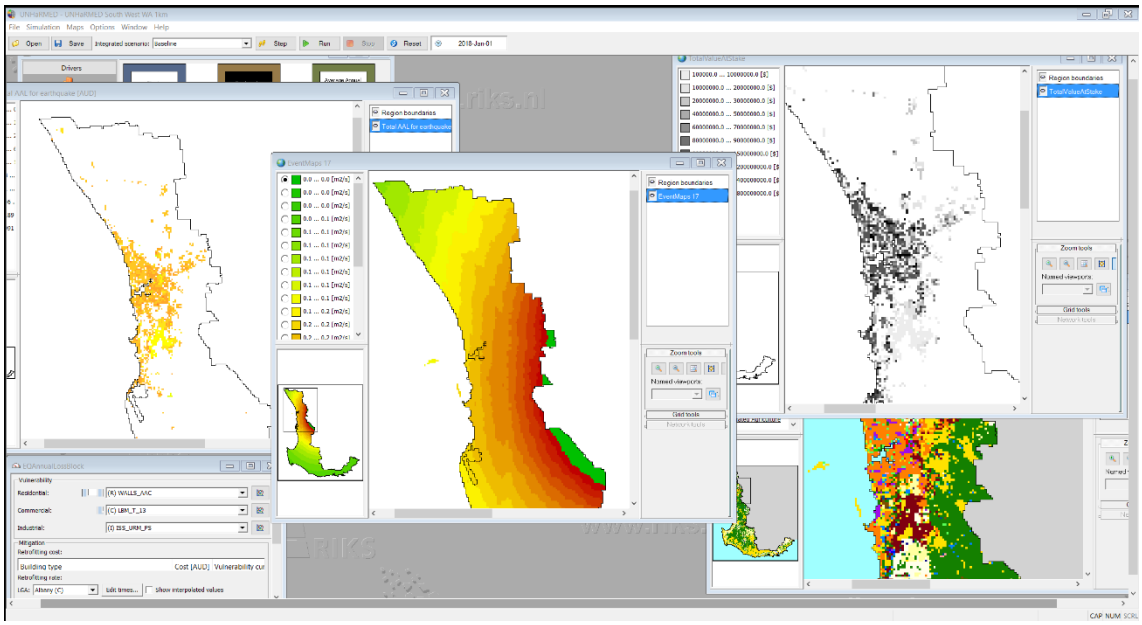
UNHaRMED is the University of Adelaide and RIKS' spatial Decision Support System (DSS) for natural hazard risk reduction planning, funded by the Bushfire and Natural Hazards CRC. The software consists of a dynamic, spatial land use change model and multiple hazard models to consider how risk changes into the future, both spatially and temporally.

UNHaRMED was developed through an iterative, stakeholder-focused process to ensure the system is capable of providing the analysis required by policy and planning professionals in emergency management risk fields. The process involved a series of interviews and workshops with members of the various State Government agencies, aligning risk reduction measures to be included, policy relevant indicators and future uncertainties, such that the system can sit within existing policy processes. This resulted in a tool that considers how land use changes through time, how various hazards interact with these changes, and what the effectives of a variety of risk reduction measures is.

Land use changes are simulated based on a number of different drivers. First there are external factors such as population growth or the decrease of natural area that determine the demand for different land uses. The land uses for every location are determined based on socio-economic factors (e.g. will a business flourish in this location?), policy options (e.g. are there policy rules in effect that restrict new housing development in this location?) and biophysical factors (e.g. is the soil suited for agriculture here?). Natural hazards are included as the specific application is set up; hazards can include bushfire, earthquake, coastal inundation, riverine flooding and extreme heat. Each hazard is modelled differently, dependent on its physical processes, and further details on each is provided within relevant reports.

UNHaRMED's land use component, Metronamica, is calibrated on historic land use changes, which is extrapolated to simulate land use developments into the future. After that, planners can experiment with scenarios, policy options and external influences such as spatial zoning plans, expansion of the road network or population growth scenarios, and assess the effect compared to the baseline scenario. Other risk reduction options are also included within UNHaRMED, allowing planners to compare the effectiveness of different measures in their ability to reduce risk.

UNHaRMED is developed in the Geonamica software environment. It comes as a stand-alone software application. The system includes the Map Comparison Kit for analysis of model results. Both tools use data format that are compatible with standard GIS packages, such as ArcGIS.



Four applications are currently developed of UNHaRMED, for different regions across Australia, in collaboration with relevant State Government agencies in each jurisdiction. Each jurisdiction determined the extent and relevant hazards to include in the software application based on existing risk understanding and data availability. These are summarised below:

South Australia – Greater Adelaide (Greater Capital City Statistical Area definition). Hazards – bushfire, coastal and riverine flooding, earthquake.

Victoria – Greater and peri-urban Melbourne. Hazards – bushfire, coastal and riverine flooding, earthquake.

Tasmania – Whole of state. Hazards – bushfire, coastal flooding, earthquake.

Western Australia – South-west corner. Hazards – bushfire, coastal flooding, earthquake.

IMPROVED UNDERSTANDING AND SIMULATION OF SOCIETAL ELEMENTS OF DISASTER RISK

Following research throughout the development of UNHaRMED, it was established that although significant research has been placed on understanding various natural hazards, the other aspects of disaster risk—exposure and vulnerability—have been neglected. Therefore, specific attention must be paid to the socio-economic components of risk (population, economics, demographics and associated vulnerabilities) to more accurately capture future disaster risk and inform strategic, proactive risk management strategies. New research efforts have subsequently been developed to assist in this and potentially be integrated within the UNHaRMED software.

UNHaRMED currently explicitly considers socio-economic components of risk through the coupled land use and building stock models. This is used to show how asset losses can be considered into the future under different scenarios of regional change and building code implementation.

This paper will provide an overview of three approaches used to better capture the socio-economic components of risk within disaster risk assessment modelling. This is currently being tested within the UNHaRMED software platform for long-term disaster risk assessment and reduction planning.

Secondly, an activity based model will be introduced which better informs land use change modelling via the accounting of dynamic, economic and population densities, and provides indicators as to future exposed vulnerable populations. Thirdly, an agent-based model approach will be presented which is being trialled to cater to improved consideration of the impact of behavioural choices, experiences and risk reduction options on bushfire risk.

The outline approaches will help to better understand the impact of social and economic characteristics and change on disaster risk. It will also enhance the understanding of various risk reduction options. This ultimately is to support more informed planning and investment decisions for a less risky future.

KEY MILESTONES

The key achievement for the project are summarised below.

UNHARMED (WA)

The first prototype of the UNHaRMED software application for WA was completed and delivered to the WA Government. Training materials were developed and end-user training was conducted.

UNHARMED (TAS)

The first prototype of the UNHaRMED software application for Tasmania was completed and delivered to the TAS Government. Training materials were developed and end-user training was conducted.

UNHARMED (SA)

The delivery and end-user training of the greater Adelaide application of UNHaRMED in 2017 has led to two follow-on projects, as outlined below.

Gawler River Flood Mitigation Planning

The Gawler River Floodplain Management Authority, which is supported by six local councils to the north of Adelaide, successfully applied for funding from the National Disaster Resilience Program (NDRP) to extend and use the greater Adelaide UNHaRMED application for strategic flood mitigation planning. This work commenced in 2019 and involves the use of UNHaRMED to support a range of participatory processes with councils, led by the research team, to explore how future risk could change under different future scenarios, as well as the effectiveness of different adaptive risk reduction strategies.

SAFECOM – State Strategic Mitigation Exercise

SAFECOM successfully applied for funding from the National Disaster Resilience Program (NDRP) to use the greater Adelaide UNHaRMED application as part of a state strategic mitigation exercise focused on the impact of sea level rise in the Port Adelaide area. This exercise will be conducted over two parts in August/September 2019.

UTILISATION AND IMPACTS

SUMMARY

The long-term disaster risk reduction frameworks and software outputs produced were co-developed with a large number of end-users for the express purpose of being utilised. They also have the potential to have a significant impact as they address many of the needs expressed by leaders in the emergency management space. The largest impediments to the uptake of the frameworks and software are the high levels of complexity and versatility. The former means that a significant level of expertise is required to implement the software and the latter means that it can be difficult for end-users to envisage the different usages the software and underpinning assessment frameworks can be put to.

In order to overcome these obstacles, a variety of case study applications are required to demonstrate the utility of UNHaRMED in a range of settings and for a range of problems. These are not included as part of current funding arrangements, making it difficult to bridge the gap between delivering frameworks and software and to co-apply them to a range of problems with end-users. While some end-users have applied for funding to enable such case studies to be completed, a broader range of applications is needed to highlight the full potential of UNHaRMED and the impact it can have. Without these demonstrations, it would be very surprising if end-users committed to embedding UNHaRMED into their policy frameworks and to sustainable funding models for its continued maintenance and development.

UNHARMED (WA)

Output description

The first prototype of the UNHaRMED software application for WA was completed and delivered to the WA government. Training materials were developed, and end-user training was conducted.

Extent of use

- Software delivery and training only occurred in March 2019, so it has not been able to be used yet.
- A working group has been established within the WA government to determine the ebst way to integrate UNHaRMED into existing processes.
- There is a desire for UNHaRMED to become a SEMC-endorsed tool for scenario testing to support advice/recommendations to government.

Output description

- The utilisation potential is very high in WA, as there is a high level of buy-in and support at both state and government levels. This is enhanced by the fact that the WA government supported the development and fast-tracking of UNHaRMED and the fact that a range of agencies, including

planning agencies, have been involved in its development from the outset.

Utilisation impact

- The utilisation impact is likely to be high, especially if UNHaRMED is adopted as a SEMC-endorsed tool for scenario testing.

Utilisation and impact evidence

- Riddell GA & van Delden H (2019) UNHaRMED user training: application for south west Western Australia.

UNHARMED (TAS)

Output description

The first prototype of the UNHaRMED software application for Tasmania was completed and delivered to the TAS government. Training materials were developed, and end-user training was conducted.

Extent of use

- Software delivery and training only occurred in March 2019, so it has not been able to be used yet.
- The Tasmanian government is keen to operationalise and incorporate UNHaRMED into existing system but has realised that they do not have the internal capacity to achieve this at present. Consequently, the Tasmanian government applied for and received funding to employ a person full time for one year to assist with the operationalisation and adoption of UNHaRMED across government agencies in Tasmania. We will be working with this person to assist this process.

Utilisation potential

- The utilisation potential is high in Tasmania, as there is a high level of buy-in and support. The fact that funding has been obtained for a persont o lead the operationalisation of UNHaRMED is very positive, but the degree to which UNHaRMED is utilised in Tasmania on a routine basis is likely to be a function of the success of this position.

Utilisation impact

- If UNHaRMED is able to be successfully embedded into government processes, utilisation impact is likely to be high, especially given the relatively small size of Tasmania.

Utilisation and impact evidence

- Riddell GA & van Delden H (2019) UNHaRMED user training: application for Tasmania.

UNHARMED (VIC)

Output description

Although the first prototype of the UNHaRMED software application for greater and peri-urban Melbourne has been completed, end-user training has not yet been conducted. It is scheduled for early next financial year based on requests from emergency services agencies.

Extent of use

- As end-user training has not been done yet, there has not been any use of UNHaRMED.

Utilisation potential

- The utilisation potential is high in Melbourne; however, a number of factors are likely to have an impact on whether this potential is realised. Although engagement by CFA has been high throughout the project, engagement by DELWP and EMV has been variable due to significant organisational/staffing changes.
- Utilisation potential is increased by strong interested by DELWP planning (especially in the land use modelling component of UNHaRMED) and, more recently, MFB. Discussions have also been held with Melbourne Water and Melbourne City Council, and there appears to be good interest from the latter.

Utilisation impact

- Utilisation impact is potentially very high, but this depends on the degree of buy-in by EMV and DELWP. The impact could be particularly high if DELWP planning were to adopt the land use model in UNHaRMED to underpin their strategic planning, as this could have far reaching impacts beyond the EM sector, enabling more holistic outcomes to be achieved.

Utilisation and impact evidence

None available.

UNHARMED (SA)

Output description

The first prototype of the UNHaRMED software application for greater Adelaide was completed and delivered to the SA government in 2017 and end-user training was also conducted at that time.

Extent of use

- The software has been installed on government computers within the fire management section of the Department of Environment and Water

(DEW). However, there has been limited usage of the software to date due to resource constraints and competing priorities

- The software is being extended and used in conjunction with the Gawler River Floodplain Management Authority to jointly explore the impact of different socio-economic and climate scenarios on flood risk and to develop long term flood mitigation strategies for the catchment.
- The software will be used as part of a state strategic mitigation exercise led by SAFECOM on the impact of sea level rise and coastal flooding.

Utilisation potential

- The utilisation potential is high in South Australia.
- Even though there is strong support at a state government level, there appears to be minimal resources and capacity at present to embed UNHaRMED into existing processes. This however is not the only pathway to utilisation.
- However, UNHaRMED is being used as part of the SAFECOM state strategic mitigation exercise, showing how the software and underpinning approach can be used in a variety of setting.
- Utilisation potential in SA appears to be strongest at a local government level, with significant interest in and willingness to provide/seek funding to use UNHaRMED for strategic planning.

Utilisation impact

- Utilisation impact is potentially very high.
- Given that UNHaRMED is being used a part of the official SAFECOM state strategic mitigation exercise, it could have a significant impact on policy. In addition, as a number of observers from other states will be invited to the exercise, this impact could spread to other states.
- The impact at a local government level is also likely to be very high, as the work with the Gawler River Floodplain Management Authority is feeding directly into strategic plans. In addition, once the utility of UNHaRMED has been illustrated at a local government level, it is likely that this will result in its usage in other local government jurisdictions/for other hazards/

Utilisation and impact evidence

- Flood research on show, South Australia DEW referring to UNHaRMED at Floodplain Management Conference: https://www.bnhcrc.com.au/news/2019/flood-research-show.
- Joint media release from (former) Minster of Emergency Management and North Queensland Recovery with SA Minister for Police, Emergency Services and Correctional Services on announcement of NDRP funding for South Australia including UNHaRMED to support GRFMA. Project noted as a highlight:

https://minister.homeaffairs.gov.au/lindareynolds/Pages/disaster-resiliience-sa.aspx.

- Riddell GA & van Delden (2017) UNHaRMED – unified natural hazard risk mitigation exploratory decision support system, user manual version 1.0, Bushfire and Natural Hazards CRC.
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- Riddell GA & van Delden H (2017) UNHaRMED greater Adelaide: utilisation workshop report, July 2017, Bushfire and Natural Hazards CRC.
- Riddell GA, van Delden H & Maier HR (2018) Urbanisation pressures & flood risk: Gawler River catchment and regional development, Bushfire and Natural Hazards CRC.

NATIONAL-LEVEL INTIATIVES

Output description

The development of the conceptual, modelling and decision support frameworks developed as part of this project, as well as the UNHaRMED software applications, have resulted in their use in a number of initiatives at national level, including:

- The National Resilience Taskforce, in terms of shaping frameworks and developing a national disaster risk reduction capability.
- A project led by the Bureau of Meteorology on mapping national heatwave vulnerability.

Extent of use

- The above projects are ongoing and have not developed products that can be used at this stage.

Utilisation potential

- The outputs from the above initiatives, which UNHaRMED and the frameworks that underpin it feed into, have significant utilisation potential.

Utilisation impact

- The outputs from these projects have the potential to have significant impact, as they are national level projects that are a collaboration between a number of larger organisations, including the Bureau of Meteorology, Geoscience Australia and CSIRO.

Utilisation and impact evidence

- Several references to our work in National Resilience Taskforce 'Guidance on Scenarios'. Holger Maier and Graeme Riddell also reviewed the report at the request of the Taskforce authors.

NEXT STEPS

From a research perspective, the next steps are to increase the capacity of UNHaRMED to represent social vulnerability. This will be achieved via:

- The development of an activity-based model to be incorporated into the UNHaRMED application for greater and peri-urban Melbourne, providing better vulnerability information (e.g. how this varies with time of day)
- The development of an agent-based model for the greater Adelaide application of UNHaRMED, which will enable an exploration of the impact of different levels of lived experience on bushfire risk.

From a utilisation perspective, the next steps include continuing to work with our end-users in South Australia, Western Australia, Tasmania and Victoria to demonstrate the utility of UNHaRMED in a range of settings and to develop sustainable utilisation pathways. However, as mentioned in the summary of the utilisation and impact section, additional funding will need to be obtained to enable the utility of UNHaRMED to be demonstrated in a number of settings for a number of different problems to provide a compelling case for why government departments should incorporate UNHaRMED into their existing processes and fund its maintenance and continued development.

PUBLICATIONS LIST

PEER-REVIEWED JOURNAL ARTICLES

1 Riddell GA, van Delden H, Maier HR & Zecchin AC (2019) Exploratory scenario analysis for disaster risk reduction: Considering alternative pathways in disaster risk assessment, *International Journal of Disaster Risk Reduction*, accepted June 30.

2 Zheng F, Tao R, Maier H., See L, Savic D, Zhang T, Chen O, Assumpção TH, Yang P, Heidari B, Rickermann J, Minsker B, Bi W, Cai X, Solomatine D & Popescu I (2018) Crowdsourcing methods for data collection in geophysics: State of the art, issues, and future directions, *Reviews of Geophysics*, 56, 698-740, DOI: 10.1029/2018RG000616.

3 Newland CP, Zechin AC, Maier HR, Newman JP & van Delden H (2018) Empirically derived method and software for semi-automatic calibration of Cellular Automata land-use models, *Environmental Modelling and Software*, 108, 208-239, DOI: 10.1016/j.envsoft.2018.07.013.

4 Riddell GA, van Delden H, Dandy GC, Zecchin AC & Maier HR (2018) Enhancing the policy relevance of exploratory scenarios: Generic approach and application to disaster risk reduction, *Futures*, 99, 1-15, DOI: 10.1016/j.futures.2018.03.006.

5 Newland CP, Maier HR, Zecchin AC, Newman JP & van Delden H (2018) Multi-objective optimisation framework for calibration of Cellular Automata land-use models, *Environmental Modelling and Software*, 100, 175-200, DOI: 10.1016/j.envsoft.2017.11.012.

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7 van Delden H, Riddell GA, Maier HR, Newman JP, Zecchin AC, Dandy GC & Vanhout R, Co-creation to support strategic disaster risk management: A generic approach for the development and use of a decision support system for risk reduction planning, *Socio-Environmental Systems Modeling*, (invited paper – submitted).

TECHNICAL REPORTS

1 van Delden H, Riddell GA, Vanhout R, Newman JP, Maier HR, Zecchin AC & Dandy GC (2019) UNHaRMED framework report: a co-creation approach for the development and use of decision support systems for disaster risk reduction, Bushfire and Natural Hazards CRC.

2 van Delden H, Riddell GA, Vanhout R, Newman JP, Maier HR, Zecchin AC, Dandy GC, Daniell J, Schaeffer A (2017) UNHaRMED – Unified Natural Hazard Risk Mitigation Exploratory Decision Support System, Technical Specification Version 1.0. Bushfire and Natural Hazards CRC.

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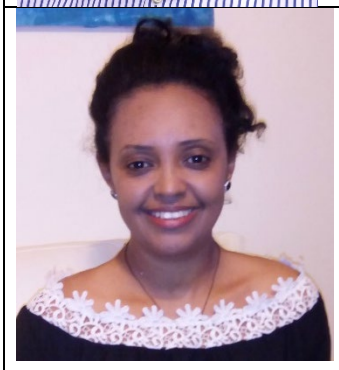
TEAM MEMBERS

RESEARCH TEAM

	Prof. Holger Maier (University of Adelaide) 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.
	Dr Aaron Zecchin (University of Adelaide) Deputy project leader, co-supervision of post-doctoral fellow and PhD students, oversight of optimisation and development of overall process and decision support system.
	A/Prof Hedwig van Delden (Research Institute for Knowledge Systems (RIKS) / University of Adelaide) 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.
	Emeritus Prof Graeme Dandy (University of Adelaide) High level oversight on optimization and development of overall process. Workshop facilitator and co-supervision of the post-doctoral fellow.

	Graeme Riddell (University of Adelaide) Responsible for day-to-day running of the project, data and model collection and conceptualisation, and stakeholder engagement processes. PhD project looks to support the integration of foresight principles and methodologies into risk assessment and management enabling more strategic responses.
	Sofanit Araya (University of Adelaide) Responsible for data analysis and processing especially for spatial information.

END-USERS

Ed Pikusa – Department of Environment & Water (SA)

Alen Slijepcevic – CFA (VIC)

Murray Carter – Department of Fire & Emergency Services (WA)

Rolf Fenner – Planning Institute of Australia (National)

Liz Connell – SA SES (SA)

Mal Cronstendt – Department of Fire & Emergency Services (WA)

Tim McNaught - Department of Fire & Emergency Services (WA)

Mike Wouters - Department of Environment & Water (SA)

Luke Roberts – Department of Premier & Cabinet (TAS)

Andrew Sanders – Department of Fire & Emergency Services (WA)

Sandra Whight – Tasmania Fire Service (TAS)

Brenton Keen – SAFECOM (SA)

Monique Blason – Department of Premier & Cabinet (SA)

Holly Foster – Emergency Management Victoria

Loretta Van Gasselt – Department of Planning, Lands & Heritage (WA)

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