Exploring the adaptive capacity of emergency management using agent based modelling

Final Report

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Cover images
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ABSTRACT

Climate change is an area full of uncertainties, and yet sectors such as Emergency Management and many others need to develop plans and policy responses regarding adaptation to these uncertain futures. Agent Based Modelling and Simulation is a technology which supports modelling of a complex situation from the bottom up, by modelling the behaviours of individual agents (often representing humans) in various scenarios. By running simulations with different configurations it is possible to explore and analyse a very broad range of potential options, providing a detailed understanding of potential risks and outcomes, given particular alternatives. This project explored the suitability of this technology for use in assessing and developing the capacity of the emergency response sector, as it adapts to climate change. A simulation system was developed to explore a particular issue regarding protection of property in a suburb prone to flash flooding. In particular the option of providing sandbag depots was explored. Simulations indicated that sandbag depots provided by CoPP or VicSES, were at this time not a viable option. The simulation tool was deemed to be very useful for demonstrating this to community members as well as to decision makers. An interactive game was also developed to assist in raising awareness of community members about how to sandbag their property using on-site sandbags. The technology was deemed to be of great potential benefit to the sector and areas for further work in order to realise this benefit were identified. In addition to developing awareness of useful technology, this project also demonstrated the critical importance of interdisciplinary team work, and close engagement with stakeholders and end users, if valuable technology uptake is to be realised.

EXECUTIVE SUMMARY

Adapting to the complex and sometimes uncertain effects of climate change is an issue of concern to a wide range of organisations tasked with developing various plans and responses (IPCC 2007).

This project aimed to explore the suitability of Agent Based Modelling and Simulation (ABMS) technology in assisting planners and policy makers to better understand complex situations with multiple interacting aspects. The technology supports exploration of the impact of different factors on potential outcomes of a scenario, thus building understanding to inform decision making. To concretise this exploration a specific simulation tool was developed to explore response capacity around flash flooding in an inner Melbourne suburb, with a focus on sandbag depots as an option to be considered.

The project was delivered by an interdisciplinary team of computer science and social science researchers at RMIT University in collaboration with partners Victorian State Emergency Services (VicSES) and City of Port Phillip (CoPP).

The three types of activities delivered by this project to achieve its objectives were the development of an agent-based simulation, data collection to inform the development of the simulation and communication and engagement activities to progress the work.

Project activities and outputs

The project resulted in outputs in the following three categories.

Software

a) Computer simulation system developed

This output is the actual decision support tool built by the project team. It simulates a flood event in Elwood and the potential to use sandbagging as response by community members.

b) Prototype game

The development of a computer game played at the household level was not a contracted deliverable but added significant value to the project by way of engagement with stakeholders. They also see it as a valuable output for community education. The character in the game receives information of an approaching storm and must sandbag to save the house from flooding.

Analysis

a) Sandbagging

Analysis was done by running the simulation multiple times with various parameters, to achieve an understanding of the potential to protect property given varying warning times and numbers of depots. It became evident that in this situation, many depots would be required to service any significant sector of the Elwood population, without excessive waiting times. As resources are clearly not available to make this feasible, further analysis on location and management of depots was not warranted.

b) Use of simulation technology

Potential usefulness of the technology was assessed by presenting the developed system to a stakeholder workshop in a hands-on session, and then exploring in discussion and by a questionnaire, their views on usefulness. Views of partner organisations also informed this analysis. The technology is seen as potentially very useful, both for policy and planning analysis, but also as a communication tool for use within the community. Some areas of further work were identified. The importance of interdisciplinary teams was also affirmed

Capacity building

a) Internal and external capacity

The project resulted in building increased interdisciplinary capacity within the project team as well as expanding the awareness of end users regarding the possibilities of ABMS technology

b) Workshop

A workshop at the end of the project, for 34 people from 21 organisations showcased the work of the project and demonstrated the software to end users who gave positive and constructive feedback.

c) Engagement and communication.

Regular meetings with VicSES and CoPP, including discussion and demonstration of ongoing work ensured the project end users were engaged throughout. Media materials including a 2 page flier, a short you-tube video, and scholarly peer reviewed publications also ensured dissemination to a broad audience.

Key Findings

Key findings resulting from the project are:

- ABMS technology for policy and planning is potentially valuable and of interest to stakeholders.
- Technical research and development work is required in order to provide a framework that will support the desired level of interoperability and re-usability
- There is a need to develop methodologies and tools to support the use of this technology
- Interdisciplinary work is essential
- In supporting the technology uptake it is important to provide funding for non-research development that impacts usability for stakeholders.
- It is important to keep stakeholders engaged throughout the process so that they contribute to all phases of the project
- It is important to manage expectations by reminding users of the ‘decision support’ nature of this technology to deal with the risk that uses assume the tool provides definitive answers
- Clear and consistent communication with stakeholders and well developed and tested communication materials are critical
- Building strong cohesive teams is important for reaping benefits of using this type of technology

1 OBJECTIVES OF THE RESEARCH

Climate change appears to be leading to an increase in the frequency and intensity of extreme events such as flooding, heat waves, bushfires and droughts. Decision making under these circumstances becomes increasingly complex and risky. Both strategic decision makers and front line response emergency management organisations require a clear understanding of their capacity to deal with these events. They also need to consider how they might increase their capacity to plan and respond over time.

Agent based modelling and simulation is an innovative way to support this agenda. It involves simulating individual agents (often but not necessarily humans) within a scenario that includes multiple variables and multiple outcomes. It is especially useful for exploring complex scenarios where standard mathematical approaches are too simplified.

An agent based modelling platform allows experimentation with many climate and non-climate variables that are available in data from sources such as the Australian Bureau of Statistics, the CSIRO, the Bureau of Meteorology, water and electricity authorities, local authorities and many more.

This research was guided by two high level objectives which are described below. Each objective allowed for close collaboration between the project partners as well as other end-users from the sectors of emergency management that deals with prevention, preparedness, response and recovery as well as work on climate change adaptation.

1.1 Introduction to Agent based Modelling and Simulation

Agent based modelling and simulation is an approach to simulation which models individual entities and their interactions with each other and the environment, in order to be able to observe the emergence of complex system level phenomena which cannot be predicted using simpler approaches such as mathematical modelling. This approach has been used quite extensively in ecology (Volker Grimm, 2005), where the individuals may be plants and animals, and in economic modelling (Tesfatsion, 2006).

It has also been increasingly used in social science applications, where it is important to model the behaviour of humans, or human organisations, and their interactions, to understand complex socio-technical systems. For example, the agent based transport modelling system, MATSim (Nagel & Flotterod, 2009) is being used by the Swiss government to analyse the impact of a speed reduction on Swiss national freeways (http://senozon.com/news), by the Berlin public transport authority to do long term planning for when Berlin gets a new airport replacing Tegel and Schönfeld (http://senozon.com/clients) and by many other clients nationally and internationally to explore questions ranging from real estate values to car-sharing programs. The Journal of Artificial Societies and Social Simulation (JASSS: jasss.soc.surrey.ac.uk/) and the Winter Simulation Conference (WSC: www.wintersim.org/) regularly report work where agent based simulations are used to inform policy and planning decisions.

1.2 Ability of ABMS as an analysis tool to support policy makers

The objective of this research was to explore the use of agent-based modelling and simulation to support informed decision making about policy and governance issues within the context of various climate change adaptation scenarios.

One aspect of this was to access the technology and its usefulness within the sector, with a focus on identifying any potential barriers or difficulties. The activities associated with this objective include the process of communication we undertook with the project partners during and after the initial system development and the demonstration activities that drew multiple decision makers together.

The delivery of this objective required a clear understanding of practitioner requirements for the associated activities to be genuinely useful to the emergency management sector. Some work towards this end was undertaken in an NCCARF funded project that took place prior to the current project and this experience highlighted the need to engage expert stakeholders and work across disciplines.

1.3 Using ABMS to support a specific emergency management scenario

An additional objective of this research project was to use an agent based modelling and simulation framework to develop a computer simulation of a chosen emergency scenario, to allow evaluation of potential responses to extreme weather events brought on by ongoing climate change. This required an iterative process of ongoing engagement and feedback from involved organisations and communities, to identify key aspects that should be modelled, as well as allow further improvement of the simulation and various underlying assumptions. The key activities linked to this objective were a series of communications with project partners and stakeholders and development of the model and simulation system.

Working towards this objective provided an opportunity to look at how the technology of agent based modelling might support an understanding of the capacity within the emergency management sector for work on prevention, preparedness, response and recovery in a changing climate.

The emergency management sector in the case of this project includes Victoria State Emergency Service (VicSES), as the responsible agency for emergency events, and the City of Port Phillip (CoPP), the partnering local government authority that maintain the capacity to deal with prevention, preparedness, response and recovery. Both organisations are required to be strategic in their approach and respond to a changing policy environment and a changing physical environment. It was not within the scope of this project to include other groups in the emergency management sector such as the Victorian Police and Metropolitan Fire Brigade. However we acknowledge the need to engage with them for decision making projects that are designed to result in policy decisions.

2 RESEARCH ACTIVITIES AND METHODS

To achieve the objectives and outcomes set out in the research plan the team undertook multiple and concurrent activities. The research team built the simulation system using an iterative process involving a series of data collection activities related to model development, together with multiple communication activities to ensure stakeholder involvement in this activity. This section describes these activities as well as the methods used to complete them.

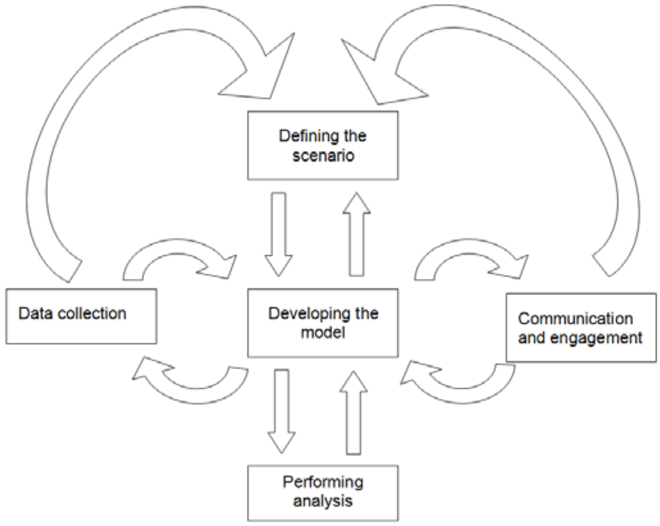


Figure 1: Agent based modelling project process

2.1 Development of a decision support tool

Building an ABM system to support a specific emergency management scenario, led the project team to undertake a series of activities to develop the model that captured an emergency response scenario particular to the case study area chosen by the project partners.

The iterative method used to develop the model included three phases of activity which are described in sections 2.1.1 to 2.1.3. Additional activities that contributed to the development of the model are data collection and engagement and communication both of which are distinct research activities and are described in sections 2.2 and 2.3 respectively.

2.1.1 Phase one: Defining the scenario

The first step in the design and development of the decision support tool was to decide the scope of the emergency response scenario that would be simulated. A scenario describes a particular situation (such as a flood), the environment where it takes place (the physical region that is flooded), the key decision makers and their activities (community members and emergency services involved in flood response).

The team worked closely with the project partners CoPP and VicSES to guide them through a process that allowed them to define a scenario that would be relevant and useful to them. To do this the following steps were undertaken. First, the technology was described and example simulation systems were demonstrated in a series of meetings between the research team and the project partners. Second, a range of possible scenarios were presented and feedback was gained on these through discussion. Third, a scenario was chosen to proceed with and a preliminary model was constructed. It should be noted that this process, although described linearly, was in fact iterative and resulted in one scenario being developed and then abandoned in favour of another that was more useful for the project partners. The first scenario developed focused on flood impacts to a local business district in the City of Port Phillip. After some discussion and attempted scenario development this was replaced by the current scenario summarised below.

It was agreed that the final scope of the model would be to simulate the scenario of community responses around flash-flooding in the inner-Melbourne suburb of Elwood with a particular focus on the potential for sandbagging depots. Elwood is subject to flash-flooding from intense rainfall within a short duration that is usually hard to predict and occurs with little advanced warning. Flooding results when the designed capacity of the drainage system is exceeded due to the intensity of the storm and the amount of rainfall experienced. Downstream areas like Elwood are even more susceptible because of the impact of additional water from further up the catchment. In February 2011, Elwood experienced severe flash-flooding and damage from an extreme weather storm akin to more than a 1 in 100 year event. This has raised questions about the preparedness of the local community for extreme weather situations, and how government bodies and emergency services can better integrate their preparedness and response services. In particular, it was agreed that the simulation would focus on the potential use of dedicated sandbag depots in Elwood, in order to evaluate if a community response strategy involving sandbagging depots could be of value in the event of future flash-flooding. The simulated system is described below:

At the start of the simulation a fixed number of randomly selected houses in Elwood are populated with one resident each. These are the households that will be used at the end to report outcomes against, such as what percentage of houses were protected. The number of houses to simulate is one of the parameters that can be configured by users before starting a simulation. Different situations or scenarios can be configured by choosing different values for the set of simulation parameters.

The start of the simulation corresponds to some time (configurable) before the flood when a storm warning has been issued. All residents that will act on the warning will do so within some set period (configurable). Residents who live in more flood prone properties are more likely to act and are also quicker to act than those never impacted. These probabilities range from 6/6 to 1/6.

After the simulation begins each resident determines whether to act and potentially starts driving to their nearest sandbagging depot. They follow the shortest road to the depot and adhere to all speed limits along the way. On arriving at the depot they wait in the shortest of a number of queues (configurable), spend some time (configurable) filling up sandbags when they reach the front of the queue, then drive back home. At home they spend a set amount of time (configurable) sandbagging their property, and after this time has passed it is assumed that their property is protected.

Amongst all this activity, the flood hits. Five successive flood levels of increasing severity are modelled, based on known flood extent data from past events. These are referred to as 5, 10, 20, 50 and 100 year events. A more serious event (for example a 1 in 100 year) is modelled as a succession of flood extents corresponding to lesser events (for example 1 in 5, 1 in 10 year events etc.).

Each event occurs instantaneously so that the entire area covered by that event is flooded immediately. If water covers a road, the road is considered impassable at that point and agents will attempt to find a new route.

The figure below shows a visualisation of one particular simulated outcome. Here green squares represents those houses that were successfully protected with sandbags (notably some households did sandbag but the flood did not reach them). Pink squares represent those houses that were flooded while sandbagging, while red squares represent those houses that did not get sandbagged in time and were flooded. The depots are marked in yellow (the numbers on them represent the total number of residents queued). Flood waters are marked in blue, where the darker shades represent increasing severity of 5, 10, 20, 50, and 100 year events. Lines represent roads, and darker shades represent increasing severity of flooding on the roads.

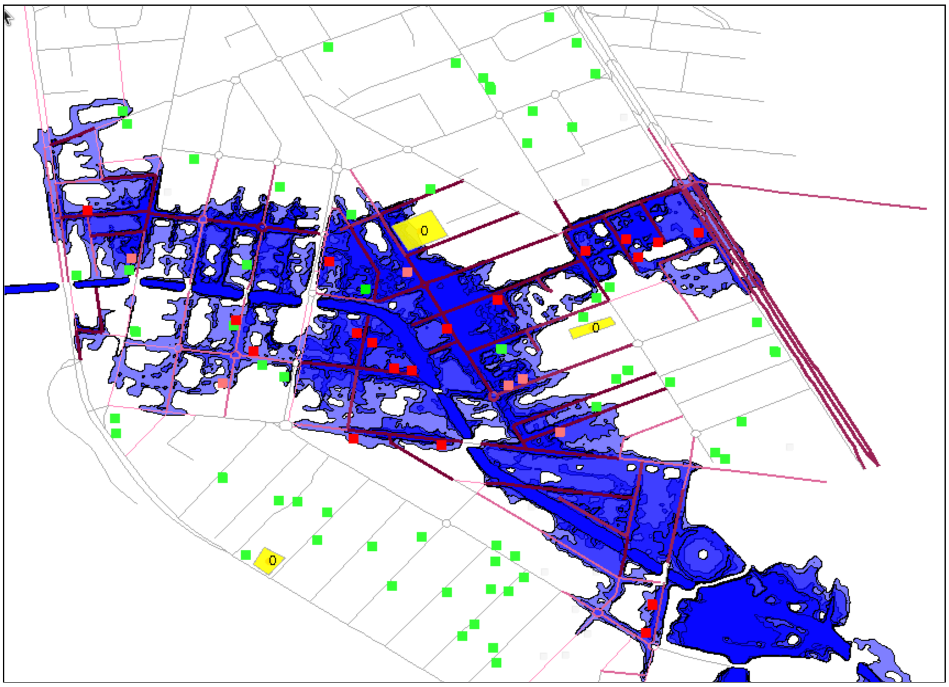


Figure 2: Screenshot of the simulation once a run has ended

2.1.2 Phase two: Developing the computer model

"The model" refers to the collection of computer modules developed representing the various aspects of the scenario (residents, depots, behaviours related to travelling on roads and queuing at depots, and so on), and their integration within a simulation platform that allows multiple "runs" of the scenario to be played out, recorded, and analysed on the computer. For the purpose of this project, we used the popular and freely available open-source simulation platform Repast Simphony. (http://repast.sourceforge.net/repast_simphony.html). The primary focus for the model is the action by agents and the possible policy measures that could be inferred from running the model.

The main components of the model are:

- Geographic data: This included the geographic information system (GIS) data for the suburb of Elwood such as the buildings and the network of interconnecting roads.
- Flood maps: Past flooding data for the Elwood region was provided by VicSES and captured the flood extend from a past major flooding event in February

2011. The flood modelling in this project is static. That is, the use of static maps means that each time the simulation is run, the flood progresses in exactly the same way. This is in contrast to say hydraulic modelling of water flow that takes into account the dynamic nature of the situation.

- Resident behaviours: The expected response behaviour of residents was developed as described in the scenario in the previous section, based on data collected through interviews, along with discussion with the project partners.
- Simulation parameters: Various simulation parameters were defined (such as the pre-warning time available before a flooding event, time it takes residents to fill and load sandbags at the depots etc.). Default values for these were chosen based on available data. A given configuration of these values describes a particular situation, and by adjusting the initial values of these parameters, different situations can be realised and simulated.
- Data output: For each simulated situation, various kinds of data are collected (such as the average waiting time at each depot) and saved. Typically, each situation is simulated multiple times in order to be able to obtain statistically significant results.

The interface of the model displays a map of the suburb of Elwood including the houses, streets and the canal. It also highlights sandbag depots where residents can line up, fill and take sandbags. The other items on the interface include various controls for the user such as play, stop and access to the parameters.

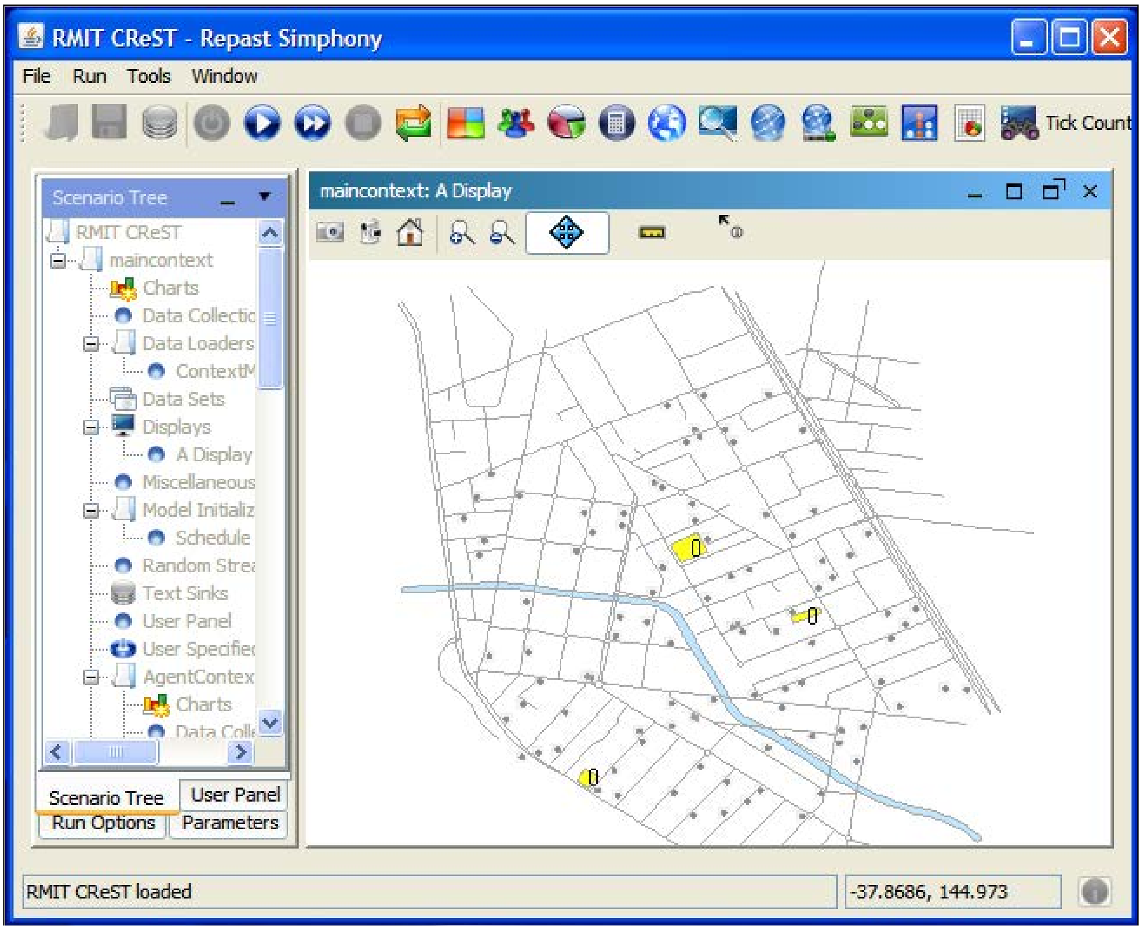


Figure 3: A screenshot of the simulation software as the simulation begins

An important part of model development is deciding on the key aspects of the situation that should be represented in a simulation. Some of these aspects should be made configurable so that they can be set to desired values at the start of a simulation. This ability to set simulation parameters is very useful in the understanding of the policy space. For example, one of the parameters that can be set by the user is the amount of time a resident spends at the depot for filling sandbags and loading into their car. This parameter has an important flow-on effect on the queue lengths at the depots and inevitably on the effectiveness of sandbag depots in saving properties. By understanding the range of values for this parameter that are sensible, decision makers can start to understand the kinds of policies that will make sense: for instance, by limiting the number of bags per resident in order to speed up the queues, or introducing alternatives to sandbagging in order to reduce the total number of residents that go to the depots.

In order to discover which details were important to the project partners a series of meetings was undertaken to demonstrate the model and discuss the possibilities. This occurred in conjunction with a program of research undertaken to draw out the behaviours and some of the physical parameters within the model.

A second important part of any modelling is to be clear on the kinds of assumptions it makes. For this reason it has been equally important for the team to present the model together with the underlying modelling assumptions to the project partners in regular meetings. Making modelling assumptions explicit not only helps stakeholders to understand the limitations of the simulation and its outcomes, but also helps them realise and articulate the importance of various aspects of the situation. As an example, in an early part of the iteration of model development, the individuals in the simulation had perfect knowledge of the flood extent and therefore always planned perfectly around flood waters. Improving this aspect of the modelling was identified by VicSES as being important, and was refined in subsequent model updates to be more appropriate such that agents planned their routes based only on the flooding they had witnessed so far. It should be noted that the modelling will always need to contain some assumptions but this process is designed to highlight the ones that can remain and those that need addressing for the modelling to be fit for purpose.

2.1.3 Phase three: Performing analysis

In order to understand outcome possibilities given the model setup and underlying assumptions, it is important to take into account the effects of uncertainty on a given outcome. Consequently, in order to understand the range and variance within the specific scenario, as well as statistical significance of difference between different configurations it is important to run the simulation multiple times with an identical configuration of parameters. As behaviours are probabilistic, identical start states will not give identical executions. The aggregated observations from all these “runs” then give a more general picture of the phenomena being analysed.

The simulation was run multiple times to answer particular questions such as the impact of warning time or of numbers of depots. The outcome data included the number of people who successfully protected their properties by sandbagging, the number of people who attempted to sandbag their properties but didn’t succeed before the flood got to their property and the queuing times.

The figure below shows one such analysis and the impact of varying the sandbag filling time at the depots, everything else being the same. Results were obtained from multiple runs of a scenario simulating six hours of activity during a 1 in 20 year flood. One resident agent was placed in every building in Elwood at the start of the simulation (a total of 2997).

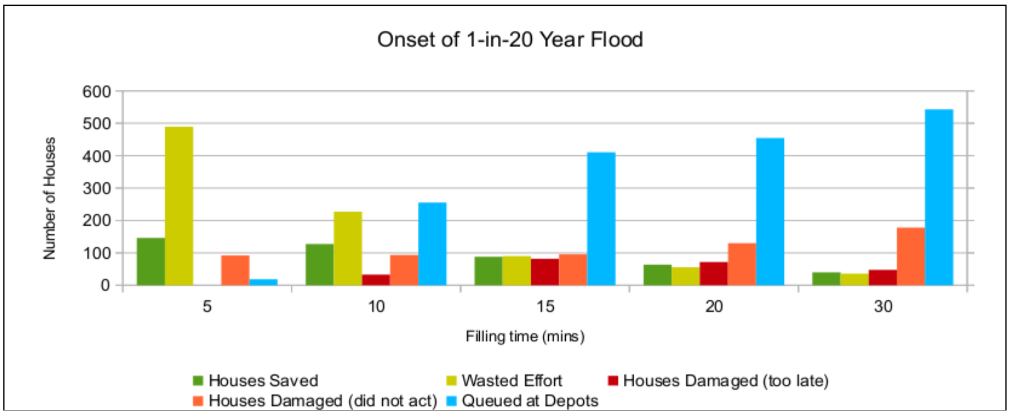


Figure 4: Graph demonstrating the number of houses affected by a 1 in 20 year flood

The configurable tool ensures that project partners can do further analysis as required.

2.2 Data collection

A model attempting to simulate a real life scenario requires data for adequate representation of many of the actions that take place within it. The amount and type of data required was determined throughout the development process. The following four sections provide a breakdown of the type of research activity that was undertaken, the purpose of the intended data and the method used to collect the data.

The four data collection activities are literature review, stakeholder interviews, secondary data collection and engagement and communication. The complete list of variables that the modelling drew on can be seen in Appendix 2: Behaviour Table.

2.2.1 Literature review

A literature review of the topic was undertaken in order to develop a typology of actions and behaviours that occur during flood events and also to reveal a context in which this work occurs.

This was performed via general internet search and a more comprehensive database search. A group of reports and other grey literature as well as peer reviewed scholarly articles were identified. General themes and key actions were identified to contribute towards adding detail and context to the scenario. Around 30 documents were found including government reports, SES reports, international emergency management reports, ABS statistics and journal articles.

Information relating to elements of the project was extracted from the literature and collated as a table of variables related to a flood event. These included the following:

- Number of sandbags used to protect an average sized home in Elwood
- List of actions people are likely to take during a flood event
- Personal attributes that lead to particular behaviours during flood events
- The effect of previous experience on action taken by people during a flood event
- Lists of things that trigger people's action during a flood event
- The complete demographics profile of the case study suburb of Elwood

2.2.2 Interviews

To strengthen the information gathered through the literature search, and to discover information specific to the scenario being built within our project, six interviews were undertaken.

The method for these interviews included gaining ethics approval, developing a flexible interview schedule that allowed information to be collected from multiple topic areas. These were policy, technical aspects of sandbagging, the technical aspects of flooding, the community experience of flooding and emergency service experience of flooding and sandbagging

The interviewees were recruited using a snowballing method that began with advice from the project partners. The six interviewees represented the two partner organisations, community members and a service delivery agency. The interviewees were taken through a semi-structured interview that lasted from 45 minutes to one hour. Interviews were recorded and transcripts of the recordings were completed.

A process of content analysis then took place using the interview transcripts. This involved firstly bringing together the data so that the responses of the interviewees questions could be grouped together in order to paint a picture. This is important in semi-structured interviews where the same questions were not asked to all participants.

Because these interviews were not seeking to theorise around some larger phenomenon the next step was to categorise the usable elements or answers to questions that could be asked of a model. An example of this includes 'what are the variables that alter the time to fill sandbags'? Although this question wasn't asked in the schedule it was answered by numerous interviewees and thus has become answered by the process of analysis.

The third step was to place all this data into a table along with the literature for use by the computer modellers.

2.2.3 Secondary data collection

Additional data was sought through the partnering organisations to develop the scenario. Some of these were required early in the modelling process due to the type of scenario developed. For example, in order to complete a flood event scenario in Elwood it was necessary to source both flooding data and spatial data that represented the suburb of Elwood.

To this end Melbourne water provided a static map based on the actual Elwood flood event from February 2011 and the project team sourced spatial data of Elwood from the internet.

Additionally, the City of Port Phillip provided data from their own internal research that was performed in 2009 and 2010. This survey based study sought to understand the level of community knowledge around the local impacts of a changing climate.

The City of Port Phillip provided a general overview of the Elwood community and a description of common community behaviours. This allowed us to understand some of the assumptions we might be putting into the model. Similarly, VicSES provided an overview of common behaviours during flood events.

2.3 Engagement and communication

The RMIT University project team engaged with the project partners, community members and other relevant stakeholders throughout the project. These activities proceeded according to the engagement and communications plan that was delivered on commencement of the project. The following four activities were key.

2.3.1 Meetings

The most important form of communication with the project partners was face to face discussion through monthly meetings designed to progress the project. Other face to face engagement included additional demonstration meetings that included people additional to the immediate project group and sought particular feedback on aspects of the project.

The project was defined and scoped in five preliminary meetings. These meetings predominantly included the RMIT project team and the CoPP and were used to identify VicSES as a project partner. In addition to this, two members of the project team attended community forums at the CoPP offices as observers.

A total of nine further project meetings took place between March and November with the project partners. The earlier meetings included agenda items that demonstrated the technology and its potential to the project partners so that a scenario could be developed. The later meetings focused on elements of the model and the data that was generated by it. In addition to the meetings a more formal workshop was held in the last few months of the project to introduce it to members of the project partner organisations for further input, prior to the final project workshop for a wider audience.

2.3.2 Interviews

The interviews undertaken by the social science team member were another form of engagement in this project. These are described more thoroughly in 2.2.2 and generated interest in the project, particularly from those not represented by the project partner organisations. Many emails were exchanged following the interviews that were essentially transactions of information about the project topic. Four out of the six interviewees also attended the project workshop held in November.

2.3.3 Media

Various media output from this project was used to communicate the intentions and outcomes of the project. The first was an A4 glossy brochure that provides a high level description of the ABMS technology, the objectives of the project, the case study area and the RMIT University Agents Group. The second was a short video providing a high level description of the project and introduction to the project team, including the two partner organisations. The third was a game developed by an undergraduate student in the School of Computer Science. The student's work was guided by the RMIT project team and informed by the ideas and interests of the project partners. The game uses the scenario of a house flooding and a character with the ability to sandbag drains, vents and doors as well as preserve important household items prior to the flood occurring. The game was presented in a special meeting in October 2012 at the St Kilda Town Hall which was attended by CoPP and VicSES personnel. It was very enthusiastically received and went on to be reviewed by the VicSES members present and subsequently improved in the next version.

2.3.4 *Workshop*

The aim of the workshop was to demonstrate the outputs of the project to a group of stakeholders in agencies that deliver services and develop policy in climate change adaptation and emergency management. Invitations were sent to stakeholders from the climate change adaptation and emergency management networks of both NCCARF and the research group. Considerable effort was put into developing materials to guide participants through the proceedings of the workshop.

Two data collection instruments were used to collect information relating to the workshop. The first was general observation which was performed by four out of the six people assisting participants during the software demonstration session to reveal how the session was received by participants. The second, an evaluation survey was completed by participants at the end of the workshop. A copy of the instruments is provided in appendix 3.

The workshop was held on 30th November 2012 from 10am till 3pm.
The event proceeded as follows:

09:45	10:00	Registration
10:00	10:05	Opening event
10:05	10:15	Welcome from NCCARF
10:15	10:35	Overview of project
10:35	12:00	Software session
12:00	12:05	Quick coffee
12:05	12:15	Stakeholder perspective- SES
12:15	12:25	Stakeholder perspective- CoPP
12:25	13:10	Lunch
13:15	14:15	Applied technology focus groups
14:15	14:55	Applied technology report back
14:55	15:00	Wrap up

3 RESULTS AND OUTPUTS

This section describes the results and outputs that arose from the activities described in section 2. The first part details the final version of the simulation plus the findings regarding the usefulness of the technology. The second discusses the data that resulted from carrying out runs of various scenarios with research questions in mind. The third part of this section of the report provides detail on the prototype game that was developed throughout the project. The fourth describes the results of the engagement and communication activities. The fifth section describes the workshop held to showcase the activities and outputs of this project. The sixth and final part of the results and output section discusses the capacity building that occurred as a result of the project and its various activities.

3.1 User experience – computer software and ABMS technology

One of the key outputs for this project is the simulation software developed using agent based simulation technology. This was completed, as described in section 2.1, through three phases of work by the project team. The result is both a decision support tool and a communications tool for the project partners.

The project partners particularly valued the use of the software as a communication tool allowing them to share decision making with the community or demonstrate some of the rationale of decisions that have been made.

It is important to note that this software does not claim to provide definitive answers to questions. Rather it can be used to explore a range of possible future scenarios and provoke discussion among those making decisions. As described previously the process used to develop the scenario was iterative with each member of the interdisciplinary team performing overlapping activities and responding to new developments. It is this kind of process that is also required when using the tool for decision making purposes.

Most of the description of the software is described in section 2.1.2 which outlines the development of the modelling.

Users can run the scenario one or multiple times with a particular question in mind. Feedback collected from users of the software suggests that users see the potential for this technology to be useful in policy making for both climate change adaptation and emergency management (see Figure 5).

Total number of respondents = 25

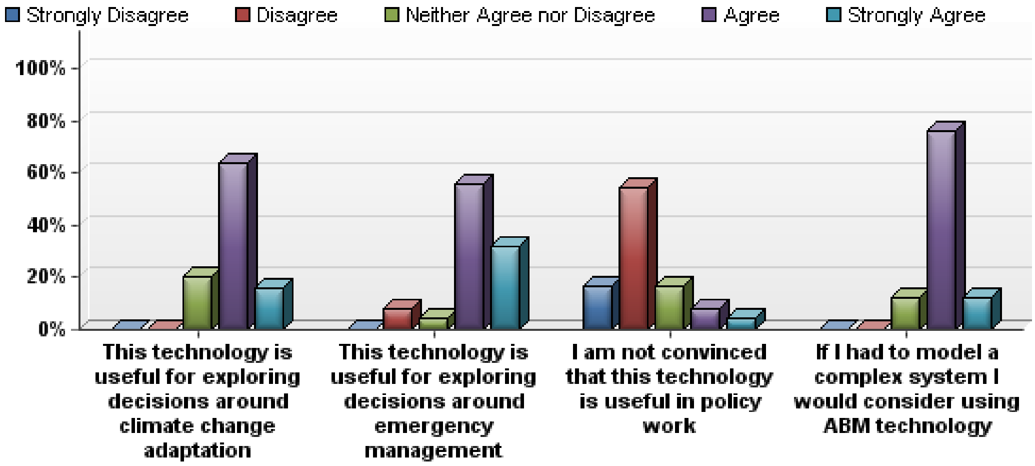


Figure 5: Results of question, "Please indicate your level of agreement with the following statements about the technology agent based modelling (ABM) and simulation"

Many of the users we tested also had a high level of confidence using the actual interface. Responding to a series of paired bi-polar statements on a ten point scale approximately 70% of users chose 1, 2 or 3 on the end of the scale that said "I would be able to use it a month from now with little help". Conversely, around 15% of users chose 8, 9 or 10 on the end of the scale that said "I would need another workshop just to start it up. This suggests a high level of confidence among a general user group – given that only one member of the user group had experience with simulation. This can also be partly attributed to the materials that were used to explain both the software and the activities that demonstrated it at the workshop.

Users also reported that it was extremely important for them to be able to change various elements of the scenario such as locations of depots and patterns of flooding. The ability to modify or add agent behaviours was also important to users as was understanding how the agent behaviour was simulated. Responses regarding the need to dynamically inspect agent behaviour during simulation were much more evenly distributed indicating lack of agreement on this point.

Total number of respondents = 25

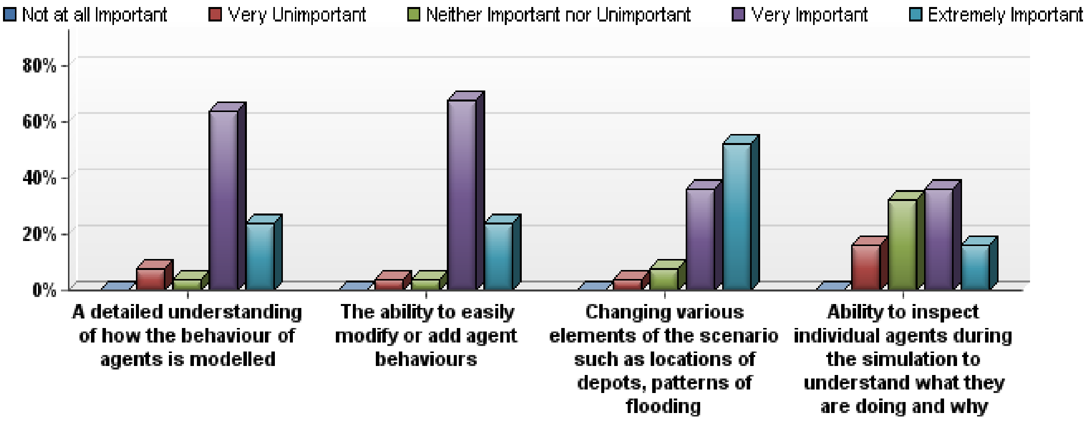


Figure 6: Results of question, "How important are the following to your experience with modelling and simulation?"

Currently the simulation can be used for the suburb of Elwood in Victoria, however the team is finalising the changes to allow data for other suburbs to be input.

3.2 Sandbagging analysis

Performing analysis on the modelling is important for building understanding for informed decision making. This part of the process does not involve watching the simulation graphically or operating the user interface, rather the user runs various scenarios numerous times to establish confidence in the patterns of outcomes observed. By systematically changing a small subset of simulation parameters over a range of their possible values, different trends in simulation outputs can be identified and quantified.

We describe below three lines of questioning that were undertaken for analysis. These relate to how the outcome of the number of houses protected was impacted by changes in (i) the flood pre-warning time, (ii) the number of depots, and (iii) the sandbag filling time. This analysis showed very early on in the modelling process, that even with many simplifying assumptions (such as no modelling of traffic congestion), sandbagging depots were unlikely to be practical. This was an intuition shared by the CoPP and VicSES team members, and was confirmed by these early simulations. This also meant that more in-depth analysis of this kind was not performed subsequently. Instead, more time was spent in improving the modelling and the graphical user interface. This is because both stakeholders saw strong value in the use of the model as a communication tool for community understanding of the nuances of sandbagging in the Elwood context.

The first line of questioning the team undertook was the effect of various warning times (the time from the original warning to flood onset) on the numbers of protected properties at the end of the flood event. This question was investigated in relation to the parameter of sandbag filling time at the depot to uncover potential relationships between the two. The model was run 20 times in each configuration giving the following results.

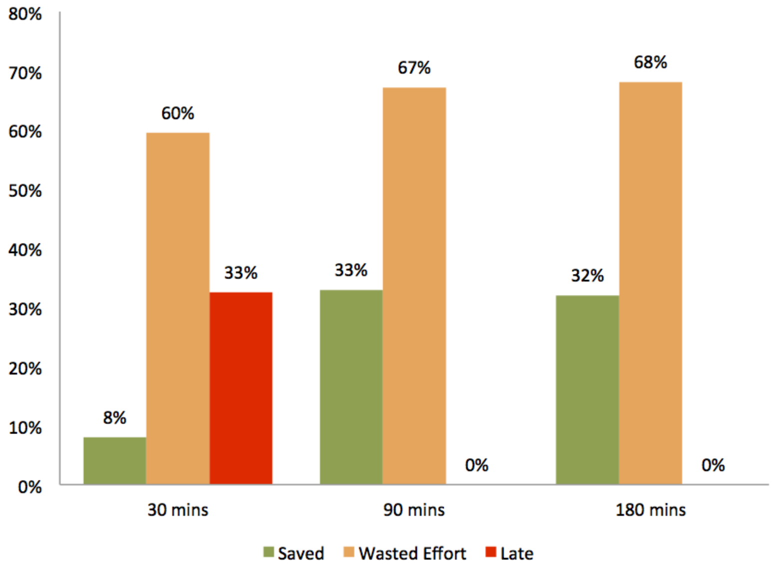


Figure 7: Impact of flood pre-warning times assuming it takes 15 minutes of fill sandbags

Figure 7 shows the average distribution of outcomes for agents that decided to act, with sandbag filling time of 15 mins. The first set of three bars show the outcomes given 30 mins of flood pre-warning time. In this setup, a third of the residents (red bar showing 33%) who acted were unsuccessful in sandbagging their homes in time before the flood hit. A second observation is that 90 mins was sufficient for those who acted to finish sandbagging prior to the flood, albeit for a majority of these the flooding never reached their homes and their sandbagging effort was “wasted”. This basic result was a useful starting point for discussion with stakeholders, and raised further questions like “What would happen if the number of people who acted was significantly larger than in this scenario?” and “What if the sandbag filling time at the depots was significantly larger?”. Figure 8 shows the result for the same set up as previously, with the only change that the sandbag filling time at the depots was increased from 15 minutes to 30 minutes. Among other things, one interesting observation here is that the time it takes for two-thirds of the population to finish sandbagging has now tripled from 30 mins to 90 mins.

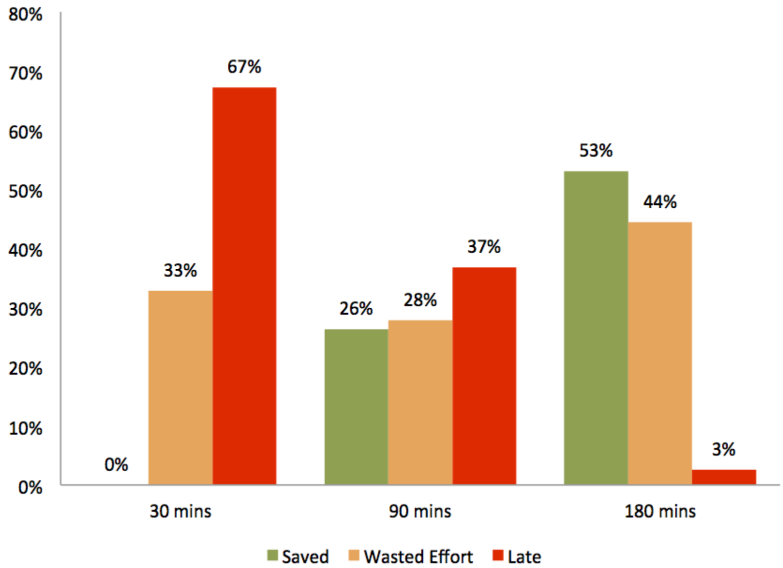


Figure 8: Impact of flood pre-warning times assuming it takes 30 minutes of fill sandbags

Firsts, it shows that sandbag filling time has strong implications for the outcomes. From a policy point of view, this means that the sandbag filling policies at the filling stations should be carefully considered. Should there be a limit on the number of sandbags allowed per person so as to keep the filling time to within say 20 mins? Or perhaps each filling station should be manned by a minimum number of volunteers in order to speed up filling and again maintain the throughput to within say 20 mins per resident?

The second line of questioning related to the impact of the number of depots on the houses saved from flooding. The results are presented in Figure 9 for a 1 in 100 year flood event, with a population of 500 residents (roughly a fifth of these will choose to act based on how often they have been flooded in the past) and assuming it takes 10

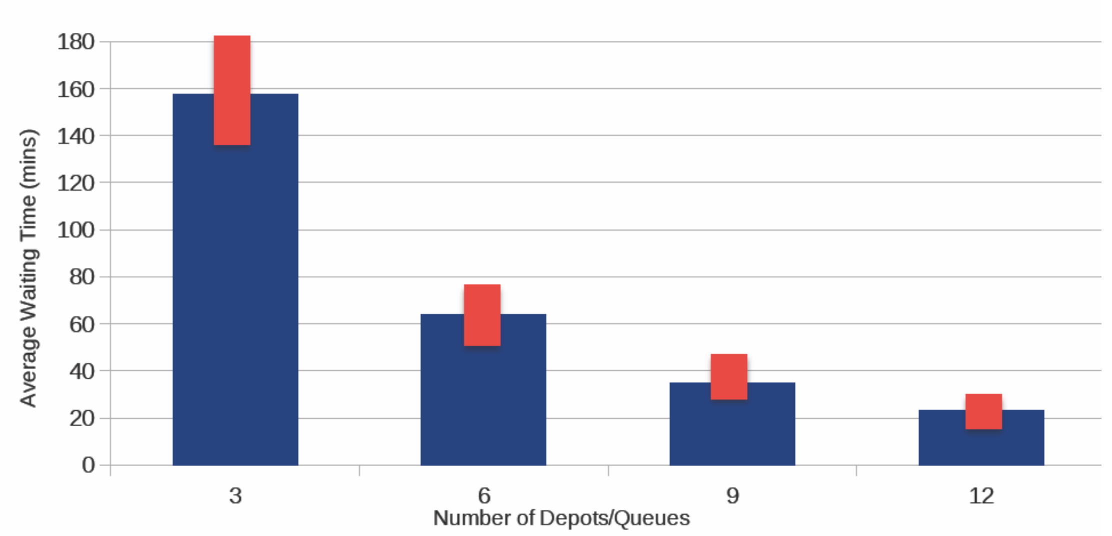


Figure 9: Average waiting time as a function of the number of depots/queues

minutes to fill sandbags, among other things. Here the depot locations were fixed and only the number of filling stations (or queues) per depot was varied. The red bars show the variation (minimum and maximum) in the collected metric over many simulation runs. The result is of course intuitive in that the more depots and queues there are, the shorter the waiting times should be. A useful observation here is that two queues per depot (bar label 6) may provide a sensible cost-benefit trade off, regardless of any other settings. Further reductions in waiting times could then be achieved by other strategic measures such as the addition of a fourth depot.

This kind of iterative analysis through simulations is useful in many ways. By collectively considering the various parameter settings, assumptions made in the simulated scenarios, and various practical constraints, policy makers can begin to understand the viability of a sandbagging solution for their particular locality.

3.3 Prototype game

As this project progressed it became clear that the stakeholders were interested in engaging with the community and building their capacity to act appropriately in flood events. The RMIT project team engaged the services of a computer science student to build a game that demonstrated appropriate responses to a flood event based on warnings available via technologies such as websites and the radio.

The resulting game allows users to control a character that has the ability to explore its environment prior to a flood warning and then a flood event that impacts on the character's home based on the actions that the character has chosen to take.

The game environment is a house with a bathroom, lounge room and garage. There are various items of value that can be put onto higher shelves and hazardous chemicals that can be placed up high out of the flood water zone. By hovering over parts of the house such as the toilet, sink, shower and vents the user sees a description of the object and a message that flood waters can enter via the object. Figure 10 below is an example of the game in play with the mouse hovering over the computer and the description box stating that this is the Bureau of Meteorology.

Figure 10: Flood! The game. An image of the game in use

The flood event begins after the character has explored the house and been alerted to a weather warning by either standing over the computer or radio. The character is then required to put items that can be damaged onto higher shelves and sandbag the places that flood water can enter. Once the flood waters arrive the places that have not been sandbagged have water enter through them and the items that have not been removed are consequently damaged.

The result is a score that provides an understanding of their performance so users can attempt to improve in the next game.

This game has the potential to be a highly engaging tool for use in flooding and sandbagging education programs. The research team is pursuing potential interest from two organisations regarding funding and support to continue with its development.

3.4 Engagement and communication

The engagement and communication outputs for this project include website content, a project video, a glossy brochure, the flood game and a scholarly publication.

3.4.1 Webpage and media

The project webpage at https://sites.google.com/site/rmitagents/projects/nccarf contains a description of the project in the context of the technology used to complete the modelling – ABMS. It also outlines the flooding event and location that the scenario is based on and discusses how the model was built in collaboration with our project partners.

The Flood game is linked to the site and the game is described. A You Tube clip of the simulation built by the RMIT project group with the CFA is also linked to this website. The final section of the webpage is a list of publications relevant to the project that can be downloaded as well as the list of project partners and links to their sites.

A glossy brochure describing the project was completed in order to provide stakeholders with an understanding of the project and the technology being used. It was developed in collaboration with project partners City of Port Phillip and VicSES. See appendix 1. This brochure is downloadable from the project website.

A short 3 minute YouTube video about the project was produced as a communication medium. The video was produced for the general public and offers a high level description of the project and introduction to the partners. This video is linked from the webpage and can also be linked from other sites.

3.4.2 Research publication

The paper titled *User understanding of cognitive processes in simulation: A tool for exploring and modifying* was presented and published at the Winder Simulation Conference 2012 in Berlin in December.

Abstract: Agent based simulations often model humans and increasingly it is necessary to do this at an appropriate level of complexity. It has been suggested that the Belief Desire Intention (BDI) paradigm is suitable for modelling the cognitive processes of agents representing (some of) the humans in an agent based modelling simulation. This approach models agents as having goals, and reacting to events, with high level plans, or plan types, that are gradually refined as situations unfold. This is an intuitive approach for modelling human cognitive processes. However, it is important that users can understand, verify and even contribute to the model being used. We describe a tool that can be used to explore, understand and modify, the BDI model of an agent's cognitive processes within a simulation. The tool is interactive and allows users to explore options available (and not available) at a particular agent decision point.

3.5 Workshop

A workshop demonstrating the outcomes of this research project was held on Friday 30th November 2012 (it is described in section 2.3.4). A total of 34 people attended the workshop with the following organisations represented.

- National Climate Change Adaptation Research Facility
- Australian Climate Change Adaptation Research Network for Settlements and Infrastructure
- RMIT University
- University of Melbourne

- Victoria University
- Victoria SES
- City of Port Phillip Council
- South East Climate Change Alliance
- Northern Alliance for Greenhouse Action
- Bass Coast Shire Council
- Mornington Peninsula Shire Council
- LIVE- flood action group
- Red Cross
- Australian National University
- Port of Melbourne Corporation
- Department of Sustainability and Environment (Victoria)
- Climate Works
- Municipal Association of Victoria
- Fire Services Commissioner
- Flood Sax
- SJB Urban

In the first part of the workshop participants were provided with one laptop between two people and guided through an activity using the software. They were given written instructions in a workshop guidebook and seven computer science specialists were on hand to assist at all times during the demonstrations. They proactively approached people to check on their progress and understanding of the software and activity.

In the second component of the workshop participants were broken into groups of 4-6 people and guided through a discussion using one of three pre-determined questions. The questions, their component parts and some of the resulting discussion are as follows.

1. **Integration into an organisation**

The natural users within an organisation would be those dealing with emergency management and risk. There was a lot of discussion around choosing scenarios carefully to fully understand the assumptions being made in the modelling. However they were also wary of overly complex modelling. Ideas for use include evacuations, energy usage, transport planning and social infrastructure planning. This group also thought that a process that gains local input would be ideal for this tool and an interface with an online survey tool to gather information from this group. Ultimately they reported that integration would require a tool embedded in an organisation that would need to be part of larger process and not be used by one role only.

1. **Usability issues**

This group focused on highlighting some of the user interface aspects of this software such as a tick count that isn't understandable and clearer functions for restarting the simulation. They listed opportunities for linking into other technologies and services such as Google maps, Sim City style graphics and community level data inputs so that users can see where vulnerable communities are.

2. **Suitable applications**

This group focused on how the technology might be applied in scenarios other than flooding. In general they thought the technology provided a good planning tool for organisations, especially local governments. This group also suggested that the technology was a good interface to community and means of communicating important information. Their ideas were simulating evacuation from big community events, community car-pooling, population growth and infrastructure needs, public transport planning, disease spread, community electricity development and finally for extreme "what if" scenarios.

Two methods of evaluation were used to identify the outcomes of the demonstration and discussion components of the workshop as well as other aspects of the event.

Firstly, the general observation demonstrated that the materials produced to guide people through activities using the software were effective. The types of questions raised by participants tended to be in relation to the usability aspects of the user interface and also around extending the visualisation of the user interface. Many of the assistants reported that if participants 'got stuck' they asked questions before referring to the workshop guide suggesting that both types of support (hands on and written) are important to people with different ways of working through problems.

The survey was returned by 25 out of the 34 participants and revealed the following findings.

- The majority of people who attended were confident in using the software
- Most people thought that the technology did have implications for policy making and that they would consider using it in their own work
- Around half of the respondents considered the interface a bit tricky to navigate
- There was a strong interest in a model that had changeable elements, such as location of depots and patterns of flooding
- There was a strong interest in being able to modify agent behaviours
- A high proportion of people agreed that the activities were interesting and helped them to understand ABM

The information gathered at the workshop and the results of the two evaluation methods suggests that with additional resources ABMS technology would be useful to policy makers in climate change adaptation, including emergency managers. A more in depth process of developing scenarios and a user interface would be required to increase the relevance and usability of the tool. The materials used to support the communication of the software are suitable for this level of communication but would obviously need to be extended as scenarios become more complex and future work should take into account the resource intensive nature of any project that attempts to educate end users in a discipline area that isn't familiar to them.

3.6 Capacity building

This section will discuss the capacity building that has occurred as a result of the project. The two key areas that capacity was built in can be described as project team capacity and end user capacity.

3.6.1 Internal Capacity

The RMIT project team was made up of computer scientists including a Professor with 15 years' experience in intelligent systems, two senior research fellows and a research assistant as well as a research assistant from the social sciences with experience in climate change policy and decision making. These two disciplines have fundamentally different approaches to research. Computer science uses a more traditional natural sciences framework of answering research questions that employs systems based thinking whereas the sociological approaches most often used in climate change work involve cultural approaches that are more likely to be iterative and question the framework of the original problem statement. In acknowledgement of these different approaches time was spent in each meeting explaining the various terminologies and philosophies. A general philosophy of open communication was adhered to throughout the project.

The two project partners from CoPP and VicSES represent the disciplines of climate science and communications. The communication process used internally by the RMIT team members was mirrored with the project partners who were consistently consulted and updated in order to ensure a shared understanding was being reached. It is this process that helped the RMIT team members to understand that the project partners had the perspective of this software being an important communication tool for them, not only a decision making tool. Based on such understanding the team were able to prioritise the features they developed to enable more effective communication.

The result of working in such a team has been genuine interdisciplinary collaboration. While a multidisciplinary team works together drawing on their own discipline methods and knowledge to contribute to the project, interdisciplinary teams use multiple methods and approaches within the project to deliver outcomes in a cohesive manner (Tress, Tress et al. 2004). Our team drew on classical scientific methods for creating a computer model as well as data collection methods drawn from the social sciences. Using these interdisciplinary methods to achieve a single outcome has increased the capacity of the team to work on projects of this nature in the future, including those that involve external partners as this project did.

The computer science team members gained access to networks of end users in the climate change and emergency management sectors as a result of direct introduction by the social science team member. This was further cemented at the workshop where team members were able to directly witness how their work was received and interpreted. The social science team member now has a good understanding of ABMS as a technology and its potential to assist policy makers and other end users.

An initial approach for using this technology with stakeholders has been developed as a result of this project.

3.6.2 End User Capacity

This project defines its end users as both the project partners and the stakeholders within professional organisations and community groups that could use the software for decision making and policy development.

We engaged these users both directly and non-directly through the various communication activities discussed in section 2.3. In developing such materials we worked under the assumption that these users would not be from a computer science background and rather were interested in climate change adaptation and emergency management from a perspective of improving the way decisions are made. This results of this project fit broadly into the genre of decision support tools which enabled us to effectively target participants for the workshop, which was the largest engagement and communication activity in the project.

By engaging our project partners consistently we have increased their level of awareness about such decision support tools and thus increased their capacity to advocate for tools such as this within their organisations.

As a result of our engagement with stakeholders the project team has various opportunities to pursue future work with organisations including Flood Sax, Municipal Association of Victoria, LIVE- Elwood, VicSES, City of Port Phillip and Bass Coast Shire Council – all subject to the availability of funding.

4 DISCUSSION

This section presents a discussion that is focussed on our findings regarding what is needed in order to make the technology explored more accessible to the target audience of policy makers and planners, and our learnings regarding interdisciplinary work with stakeholders. We discuss each of these areas separately and then conclude with a brief summary.

4.1 Using ABMS technology for policy and planning

Agent based modelling and simulation is increasingly being used by social scientists to model, explore and understand complex situations where human behaviour is involved (cite Page and Miller book, see proposal). There are an increasing number of examples where the technology is indeed used in planning and policy making (e.g. Berger 2001; Lempert 2002). However, it is still a long way from the situation where most potential users are aware of and understand this approach and its potential for aiding in decision making. This project aimed to:

- Increase awareness of ABMS technology amongst relevant stakeholder groups
- Assess the potential usefulness of the technology as perceived by those stakeholder groups exposed
- Explore the necessary or desirable extensions to the technology, required to meet stakeholder and application needs.

The importance and relevance of non-technical aspects, such as interdisciplinarity and stakeholder engagement are explored separately in the following section. The project has made an initial step in raising awareness of the technology, primarily through the end of project workshop, attended by 34 attendees from 21organisations in the sector. The majority of these attendees felt that they had gained a good introductory understanding of the technology, and believed it would be useful in policy and planning for climate change adaptation and emergency management (as supported by our questionnaire results, section 3.1). In addition we would expect some additional exposure as a result of onward dissemination from workshop attendees, as well as the website and relevant publications. We have already published one paper in the Australian Journal of Emergency Management, and a further paper is planned for next year, based on the flood response application.

The majority response from workshop attendees was that this technology was indeed potentially useful, and that they would consider using it within their organisation if the need arose (as per the survey responses represented in the graphs in figure 5 and 6 in the survey reported in section 3.1). The representatives of the two organisations with whom we worked closely (SES and CoPP) also confirmed that they now understand this technology, and see it as being potentially very useful, both for analysis and for supporting community based discussion and engagement.

Analysis of useful or necessary technology extensions to meet stakeholder or application needs, is based on both stakeholder responses and our own observations on the basis of working with the relevant groups. We discuss the main points under the subsections below.

4.1.1 Framework support for modularity and interoperability

Simulation systems involving people and complex issues often need to model a number of different aspects of the situation in order to obtain a well-informed understanding. For example a more detailed simulation of the flood management scenario would likely need to model the activities of SES members, who may assist with sandbagging or depot management, but also have many other calls on their time. Similarly, traffic would need to be modelled in more detail than it is now. Often there are detailed simulations built with long term expertise and effort, such as MATSim in the area of traffic flow (Nagel and Flotterod 2009), Phoenix (Tolhurst, Shields et al. 2008) in the area of fire behaviour, or UrbanSim (Waddel 2002) in the area of urban development. However there are no frameworks available for easily combining these different pieces to more efficiently obtain a simulation for a complex scenario.

One reason for the importance of re-using existing software rather than re-developing, is efficiency in obtaining a simulation covering many aspects. However an equally important consideration is that organisations want to use systems and data with which they are familiar and which they trust. For example CFA had as an absolute requirement that any fire modelling be done using the well-established Phoenix fire simulator. This project has made some progress in this area, combining different tools and modules. However substantial work is still needed.

In the current projects we have only combined modules which do not interact with respect to changing the environment or the agent state. For example neither the fire behaviour, nor the flood behaviour is affected by the agent behaviour. If we wished to have the fire or floodwater respond to agent behaviour such as sandbagging or water bombing, then interaction between modules during the simulation is required. While it is possible to develop such interaction on a case by case basis, a preferred approach is to develop a framework which provides support for such interaction and guidance as to how to implement it. This is an important area of future technical research.

There are also areas where support for modularity and re-usability can be developed, without the need for technology research. These include such things as tools for easy interchange of street maps for different areas, using standard resources such as Open Street Maps, or tools for inclusion of different environmental impacts such as bushfire or flood progressions. We have made progress on understanding the requirements here and are in the process of finalising tools specific to the two applications developed. These can be further generalised as student programming projects over the coming year, and made available via our website.

4.1.2 Methodology and tools

There is a clear need for methodology and tools to support the process of developing ABMS systems for use in decision support for policy and planning. It is critical that such a methodology support the interdisciplinarity and stakeholder engagement that we and others (Guyot, Drogoul et al. 2006) have found to be crucial if systems are to be accepted and used. Such a methodology can only be developed on the basis of ongoing experience, and as a result it is important to nurture and develop interdisciplinary teams where such a methodology can be developed over time.

We have made some initial steps in this direction, and have prototyped one support tool for assisting with a particular aspect of participatory modelling (Scerri, Hickmott et al. 2012). However much remains to be done, both in developing tools, and in bringing together and making accessible, tools which already do exist.

One important area in the use of this technology is the careful and thorough analysis of output data, as well as tools and methods for verifying models. Modularity as described above is one approach to and aspect of model verification, in that more limited models can more readily be understood and verified by domain experts. A simulation model with multiple configurable parameters gives rise to an exponential number of scenarios, and even with relatively limited parameters this quickly becomes many more scenarios than can feasibly be run and analysed. It is important to ensure that sufficient and appropriate coverage is obtained. Methods such as Latin hypercube, which is a statistical method for generating appropriate configurations of parameter values, exist, and tools to assist with this have started to become available (Hernandez, Lucas et al. 2012). These need to be collected, explained and made accessible to a broad user base. There is also research needed in how to extend understanding of configurable discrete parameters, to agent behaviours and their specific effects on a simulation.

4.1.3 Domain expertise and modules

As ABMS is more widely used within specific domains, domain expertise develops and specialised domain specific ABMS systems become available, such as in traffic management, e.g., MATSim (Barrett, Eubank et al. 2005), urban development, e.g., UrbanSim (Waddel 2002), or epidemiology, e.g., EpiSimS (Barrett, Eubank et al. 2005). Climate change adaptation and emergency management do not yet have the level of domain expertise that has been developed in some other areas. It would be beneficial to foster development of this expertise, preferably within a framework of interoperable modules.

4.1.4 User Interface issues

User interface and general usability issues are always important in software uptake. This is also the case with this technology. We have not seen any evidence of issues requiring development of specialised user interface technologies. What is clearly important is close interaction with users to obtain and address feedback on the myriad small issues that can negatively impact usability. While this does not (as far as we have ascertained) require technical research, it does require technical resources, combined with interdisciplinary teams and close engagement with user groups, in order to continually address these issues so that they do not stand in the way of use and uptake. This requires allocation of development resources, integrated with, but in addition to research resources, in order to efficiently progress these aspects.

4.1.5 Summary

In summary we note the following important points:

- The target group found the technology potentially valuable and of interest for policy and planning
- Technical research and development work is required in order to provide a framework that will support the desired level of interoperability and re-usability
- There is a need to develop methodologies and tools to support the use of this technology
- Interdisciplinary work is essential
- In supporting the technology uptake it is important to provide funding for non-research development that impacts usability for stakeholders.

4.2 Interdisciplinary team work and working with stakeholders

4.2.1 Interdisciplinary teams

Working beyond one's discipline boundary contains significant challenges that, once worked through, result in significant capacity for working in this way in the future. The key challenge for members of this research team in working outside their area of expertise was the requirement for explanation and continual discussion of the use of different theoretical bases and methods. Other challenges we faced, difference in communication styles, ways of formulating questions and approaching research problems, are all documented in the literature as common to interdisciplinary work (Bull and Oughton 2006).

A key part of working in an interdisciplinary team is developing ways to translate work produced by one discipline into another. In our case an important outcome was translating the social science data into parameters for the simulation. Our experience in not unique – there are other cases where social science data produced for simulations is stated as being difficult to "quantify, calibrate, and sometimes justify" (Bonabeau 2002p.7287).

4.2.2 Stakeholder engagement

The stakeholders for this project were our partners, VicSES and City of Port Phillip, the interview participants, our networks and the workshop participants, many of whom were already engaged in our work in some way prior to the workshop.

Being able to engage stakeholders is essential to the process of developing an agent-based model with relevant parameters and realistic assumptions. The iterative approach we used between our team and the project partners to demonstrate and critique the simulation updates and discuss the data findings was one we feel was very successful and would repeat in future projects.

It should be stated that while it is critical to the development of a rigorous simulation to engage end users, an outcome of this approach is that projects like this require a high level of resourcing. We found this in our experience of this project and it is a finding that is supported by a literature review on the topic of working with end users to create a simulation (Lucas 2011).

4.2.3 Communicating results

Communicating the modelling and the results of the model to a non-technical audience is something that many ABM projects have found challenging (Lucas 2011) and this project was no exception. Understanding the implications that arise out of the simulation data is equally important to developing a rigorous model. We approached this via our standard means of communication, which was a series of meetings were results were presented and discussed. In this way the project partners were able to respond to the findings as they occurred, hence our understanding of the lack of resourcing for many sandbagging depots.

4.2.4 Summary

To summarise this section we offer the following findings:

- It is important to keep stakeholders engaged throughout the process so they are more able and inclined to contribute in key phases of the project

- Managing expectations by reminding users of the ‘decision support’ nature of this technology to deals with the risk that uses assume the tool provides definitive answers
- Clear and consistent communication with stakeholders and well developed and tested communication materials
- Building strong cohesive teams is important for reaping benefits of using technology like this

4.3 Conclusion – where to from here

This project has been valuable both for building awareness of ABMS technology as a potential resource for policy and planning, and for building interdisciplinary knowledge and skills, bringing technology, social science and end users together.

This project has confirmed that there is a vast potential for this technology to contribute substantially to many areas of policy and planning involving complex systems of interactions. However it is not simply a matter of a marketing campaign. Work is needed to co-develop modular frameworks, content modules which can be reused, and to continue to build and develop the necessary interdisciplinary understandings and skill sets, via an ongoing program and projects. The potential is there for large rewards with substantial investment, but there is also potential for incremental ongoing development. Building interdisciplinary understanding does take time, and it would be hoped that productive teams can be sustained and developed, rather than being regularly dispersed and rebuilt with new members, with the resulting overheads.

The project has been successful at introducing the technology research members to end-user networks. It is hoped that this will facilitate further funded projects that can gradually be shaped into the kind of research program which is able to deliver the level of impact which the technology potentially offers. In pursuing this objective it is important to maintain a balance between different disciplines, a balance between research and application, a balance between long term vision and shorter term benefits, and an ongoing commitment to engagement and the need to work in teams to contribute to solving large and difficult problems.

REFERENCES

Barrett, C. L., S. G. Eubank, et al. (2005). "If Smallpox Strikes Portland." Scientific America 29: 54-61.

Berger, T. (2001). "Agent-based spatial models applied to agriculture." Agricultural Economics 25: 245-260.

Bonabeau, E. (2002). "Agent-based modeling: Methods and techniques for simulating human systems." PNAS 99(3): 7280-7287.

Bull, L. J. B. and E. A. Oughton (2006). "'What Do You Mean?' The Importance of Language in Developing Interdisciplinary Research." Transactions of the Institute of British Geographers 31(3): 371-382.

Guyot, P., A. Drogoul, et al. (2006). Power and negotiation: lessons from agent-based participatory simulations. The fifth international joint conference on Autonomous agents and multiagent systems, Japan.

Hernandez, A., T. Lucas, et al. (2012). Selecting Random Latin Hypercube Dimensions and Designs Through Estimations of Maximum Absolute Pairwise Correlation Behaviour. Winter Simulation Conference, Berlin.

IPCC (2007). Fourth Assessment Report. Climate Change 2007, IPCC, UNEP.

Lempert, R. (2002). "Agent-based modeling as organizational and public policy simulators." PNAS 99(3): 7195-7196.

Lucas, P. (2011). "Usefulness of simulating social phenomena: evidence." AI & Society 26(4): 355-362.

Nagel, K. and G. Flotterod (2009). Agent-based traffic assignment: going from trips to behavioral travelers. 12th International Conference on Travel Behaviour Research, Jaipur.

Scerri, D., S. Hickmott, et al. (2012). User Understanding of Cognitive Processes in Simulation: A Tool for Exploring and Modifying. Winter Simulation Conference Berlin.

Tesfatsion, L. (2006). Agent-Based Computational Economics: A Constructive Approach to Economic Theory. Handbook of Computational Economics (pp. 831-880).

Tolhurst, K. G., B. J. Shields, et al. (2008). "PHOENIX: development and application of a bushfire risk management tool." Australian Journal of Emergency Management 23(4): 47-54.

Tress, G., B. Tress, et al. (2004). "Clarifying integrative research concepts in landscape ecology." Landscape Ecology 20: 479-493.

Volker Grimm, S. F. (2005). Individual-based Modeling and Ecology. Princeton University Press.

Waddel, P. (2002). "UrbanSim: Modeling Urban Developement for Land Use, Transportation, and Environmental Planning." Journal of the American Planning Association 68(3): 297-314.

APPENDIX 1: PROJECT BROCHURE

Simulating the Effectiveness of Sandbagging for Flash-Flooding in Elwood

RMIT UNIVERSITY

Summary

This study is using agent-based modelling and simulation tools to assist in exploring key actions that may be taken to reduce the impacts of flash-flooding in inner-Melbourne suburbs such as Elwood. Through consultation with council, emergency services, and the community, researchers from RMIT University are building computer simulations that will help answer questions like:

- Are sandbag depots likely to be effective in limiting damage to homes during a flash-flooding event?
- If the creation of sandbagging depots is feasible, which locations would be most suitable?
- What queuing and filling processes would be effective?
- How might current community practices and behaviour inform such simulations?

About this study

This work is part of a project titled Exploring the Adaptive Capacity of Emergency Management through Agent-based Modelling that is funded by the National Climate Change Adaptation Research Facility and led by the RMIT Agents group in collaboration with City of Port Phillip and Victoria State Emergency Service.

Recent flash-flooding in Elwood has raised concerns about community preparedness for extreme weather events.

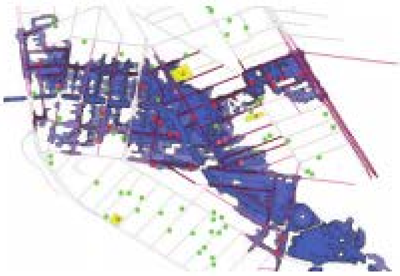
Elwood is subject to flash-flooding, from intense rainfall within a short duration, that is usually hard to predict and occurs with little advanced warning. Flooding results when the designed capacity of the drainage system is exceeded due to the intensity of the storm and the amount of rainfall experienced. Downstream areas like Elwood are even more susceptible because of the impact of additional water from further up the catchment. In February 2011, Elwood experienced severe flash-flooding and damage from an extreme weather storm akin to more than a 1 in 100 year event. This has raised questions about the preparedness of the local community for extreme weather situations, and how government bodies and emergency services can better integrate their preparedness and response services.

Agent-based modelling is being used to simulate and understand sandbagging possibilities during flash-flooding.

In this study, a multi-disciplinary team of social and computer science researchers from RMIT University are working closely with City of Port Phillip and Victoria State Emergency Service to develop computer models to simulate community behaviours around the use of sandbagging depots as a possible means of reducing the impacts of flash-flooding in Elwood. The investigation was prompted by images of community members using sandbagging for riverine flooding in regional Victoria over January/February 2012, which suggested that sandbagging is effective for most flooding situations.

Simulating Sandbagging Activities During Flooding

Discussions and interviews with the community, council, and emergency services, have been used to extract a better understanding of flash-flooding events and experiences in Elwood.



The developed models use flooding data from past events, and focus on movements of people between their homes and predefined sandbagging depots. Multiple simulation "runs" of the scenario can then be used to answer questions like "Are sandbag depots likely to be effective in limiting damage to homes during a flood?", and "How many would be needed and what would be good locations for such depots?" These simulations can assist in defining strategies for protecting as many homes as possible before an impending flood, and also help to demonstrate the kinds of activities that are effective, ineffective, or even detrimental during flash-flooding events.

Simulation is a valuable tool for emergency management to evaluate existing as well as potential future operational policies and procedures. This is an iterative process of ongoing engagement and feedback from involved communities and local government organisations, to allow further improvement of the developed models and their underlying assumptions.

Agent-based Modelling and Simulation

Traditional mathematical modelling of complex systems is often too rigid and simplistic when it comes to representing social choices and behaviours. In reality, people are not perfect, and are prone to error and bias. An innovative way to support the agenda of capturing people's choices and behaviours is through the use of agent-based modelling. This approach models behaviours at the level of the individual or "agent", and by simulating the interactions between agents in a population, different emerging phenomena can be observed and analysed.

This approach models behaviours and interactions at the level of the individual allowing patterns of behaviour to emerge.

Agent-based modelling is an analytical approach that provides an intuitive way of capturing the behaviour of different actors and the important chains of influence between them. Through repeated simulations, it allows us to gather information about a range of possibilities, together with how key factors interact to influence these outcomes.

Agent-based Modelling and Simulation

Technology for representing and analysing complex systems involving many independent decision makers, such as those found in social systems, financial markets, and ecosystems.

Motivation

Mathematical models of complex systems with interacting individuals are either too simple or too perfect. "Agents" can be made to behave something like real people: prone to error and bias.

Benefits

It is more intuitive to model behaviours of individuals and their interactions, and let patterns of behaviour emerge from those. This type of modelling is also helpful for understanding complex outcomes.

About the RMIT Agents Group

The RMIT Agents group is internationally recognised in the area of intelligent agent systems with research spanning more than 15 years. The group has built a strong reputation for producing world-class research and undertaking successful collaborations with industry through numerous Australian Research Council Discovery and Linkage grants.

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APPENDIX 2: BEHAVIOUR TABLE

Action and behaviour modelling- Sandbagging and flooding

Information type	Behaviour/action	Source	Modelling possibilities
	Sandbagging		
Activities occurring at sandbag filling stations	Accidents during sandbag filling due to use of shovel near hands	Interviews (EG)	Model an accident and/or agents slowing down to account for safety
Timing of picking up sandbags	-minimum 45 mins door to door;	Interviews (JK)	
Skill of sandbag filling	If filling by hand two people are required (one to hold and one to shovel); Back aches after filling approximately 12 sandbags; Layering and angling is more difficult than can be understood through common knowledge; level of exhaustion just from filling bags can affect the placement	Interviews (EG)	Model level of fitness to effect timing of bag filling;
Timing to fill a sandbag	Two people approximately 1 minute per sandbag (potentially longer as more are filled due to tiredness)	Interview (EG; JK)	
Placement of sandbags around home	Doorways, vents and windows at ground level	Interviews (AG; EG), partner meetings	Model movement around house and timing
Number of sandbags used to protect home	Minimum 20 for an average three bedroom home	Interviews (EG), literature (SES Sandbag Reference Guide)	Model timing of collection and placement
How to sandbag	Wall should be short and low; the base should be three times as wide as the height; bags should be stacked in a staggered fashion like brickwork so that open end of one bag is covered by next; doors, low windows and vents should be prioritised	Literature (College of Agriculture and Biological Sciences, 2010); interviews (JK; EG; AG)	
	Flooding		
Flash flood characteristics	Agents moving around flood waters in particular ways	Interviews, partner meetings, literature	Model flooding as occurring quickly, little time for preparation,
Ways people hear about a flood	• See it coming • Hear from a friend or neighbour • Bulletin board from SES or other emergency agency • Bureau of Meteorology • Council website • Media alert such as television or radio • Social media • SES alert within neighbourhood such as loud speaker or door knock	Interviews (AG; LR), literature (Dawson, 2011)	Model the effects of what people do based on how they hear about the flooding
Levels of flood preparedness	Past experience with flood increases the level of preparedness of agents and increases their level of action during a flood; likewise previous false alarms can lead to increased complacency; awareness does not lead to preparedness (Dawson found that 52% of UK residents were aware of flood risk but only 7% had prepared).	Interviews (AG; LR; DR; JR), literature (CoPP social research; Becker et al 2007; Dawson, 2011 Heatherwick, 1990; Handmer, 2000)	Model levels of actions according to numbers of past houses flooded (taking account of housing turnover rate)
Levels of flood preparedness	Levels are always lower than authorities hope for. Under 8% had an emergency kit according to one study of four NSW communities	Literature (Becker et al, 2007); interviews (JK, LR); project meetings	
Risk perception	Risk averse more likely to evacuate	Literature (Pfister, 2002),	Model those likely to evacuate as also being more likely to get sandbags
Risk perception	Post flood event evaluation data shows that only 10% of town evacuated after requested; 97% knew of the warning; 75% believed they were not under thread of flood	Literature (Pfister, 2002)	
Where might people be when a flood occurs	• Home [what is the likely demographic] • Work [what is the likely demographic] • School • In someone else's business • Outdoors • Driving • On public transport	Literature (Dawson, 2011; ABS, 2006)	Actual percentages can be modelled depending on what time of the day the flood occurs. ABS has data on car ownership, employment status, parental status etc.
Safety in flood events	Likelihood of death or injury might be determined by the depth of the flood water and the velocity of the flood water	Literature (Dawson, 2011, p.179).	

APPENDIX 3: DATA COLLECTION INSTRUMENTS

Agent based modelling workshop - feedback survey

We appreciate your participation in today's event. In order for us to understand the outcomes from the day we ask you to please complete this survey, which should take approximately 5 minutes.

This survey is part of the broader project evaluation which has gained approval from RMIT University's ethics committee. This survey is voluntary and your responses are anonymous. By returning this survey we assume you consent to participating. If you do not wish to participate please do not return this survey.

If you choose please answer the questions and return to the collection box on your way out of the room.

Q1: Please indicate your level of agreement with the following statements about the technology of agent based modelling (ABM) and simulation.

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
This technology is useful for exploring decisions around *climate change adaptation*	❍	❍	❍	❍	❍
This technology is useful for exploring decisions around *emergency management*	❍	❍	❍	❍	❍
I am not convinced that this technology is useful in policy work	❍	❍	❍	❍	❍
If I had to model a complex system I would consider using ABM technology	❍	❍	❍	❍	❍

Q2: If you were going to use this kind of modelling in your job role, what situation would you study and why?

Q3: Thinking about the useability of the software, please indicate the strength of your opinion using the ten point scale below.

	1	2	3	4	5	6	7	8	9	10	
Software was simple to use	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍	It was far too complex
Interface was intuitive	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍	Difficult to navigate
I would be able to use it a month from now with little help	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍	I would need another workshop just to start it up

Q4: How important are the following to your experience with modelling and simulation?

	Not at all Important	Very Unimportant	Neither Important nor Unimportant	Very Important	Extremely Important
A detailed understanding of how the behaviour of agents is modelled	❍	❍	❍	❍	❍
The ability to easily modify or add agent behaviours	❍	❍	❍	❍	❍
Changing various elements of the scenario such as locations of depots, patterns of flooding	❍	❍	❍	❍	❍
Ability to inspect individual agents during the simulation to understand what they are doing and why	❍	❍	❍	❍	❍

Q5: Based on your experience with the activities and discussion in this workshop, please indicate your level of agreement to the following statements.

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I found the activities interesting	❍	❍	❍	❍	❍
The activities helped me to understand agent based modelling	❍	❍	❍	❍	❍
The activities helped me to understand the main elements of a scenario	❍	❍	❍	❍	❍
I have developed an appreciation for the strengths of this kind of approach	❍	❍	❍	❍	❍
I understand the importance of statistical analysis of the simulation data	❍	❍	❍	❍	❍
Modelling and simulation can assist in policy making activities	❍	❍	❍	❍	❍

Q6: Please summarise the most valuable information or concept you learnt today?

Q7: What remains unclear for you?

Q8: Why did you choose to attend this workshop? (tick all that apply)

❑ Interest in modelling and simulation
❑ Interest in emergency management
❑ Interest in climate change adaptation
❑ Networking
❑ Support RMIT
❑ Support NCCARF
❑ My organisation wanted me to attend
❑ Other ____________________

Q9: Please indicate the level to which you agree with the following statements.

	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
The presenters were engaging	❍	❍	❍	❍	❍
The presenters provided content that was relevant	❍	❍	❍	❍	❍
The workshop was a good networking opportunity	❍	❍	❍	❍	❍
The workshop was a good learning opportunity	❍	❍	❍	❍	❍

Q10: What is your age group?

❍ 18-24
❍ 25-34
❍ 35-44
❍ 45-54
❍ 55-64
❍ 65-74
❍ 75 or over
❍ Prefer not to answer

Q11: What is your gender?

❍ Male
❍ Female

Q12: Please provide a general description of your job role or background.

Thank-you for completing this survey

Data collection instrument
Workshop participant observation

The data collection for today's workshop is part of a broader project evaluation which has approval from RMIT University's ethics committee. The purpose of the evaluation is to gain a deeper understanding of the user experience with the technology and the model for this project. We also wish to know how effective our communication about the model is as part of this event.

Your role
Aside from your role in assisting participants we are also requesting that you act as a data collector for the project evaluation. We would like you to observe participant's interactions with the technology, each other and the event staff and document your observations. You can collect data according to the categories and questions on this form as well as providing your own general reflections.
In doing this please note the following:

- **Do not** list participant's names
- **Do not** list identifiable characteristics job title or anything else that could be traced back to an individual
- If participants ask you about data collection advise them that you are recording general observations only and no identifiable data is being collected (if they have any further questions they can speak to Shae Hunter)
- Keep track of the approximate number of people you assist and what you assist them with
- Record simple observable situations like this 'I assisted 5 people during the first activity', 'most people I observed found changing the parameter difficult', 'about three people appeared frustrated by not being able to find what they needed on the interface'.

Also record more specific things like: Asking how a part of the interface works (3 out of 8 people I worked with); How did the modellers come up with [parameter]? (2 people); People were frustrated with x (3/8); general sense of enjoyment 2/8)

Data collection categories

Usability
Things to look for and record: asking for assistance for the same task, intuitive use of the interface,
Enjoyment- frustration, focus, interaction with group, laughing, showing resistance to the tasks.

Learning
Things to look for: ah ha moments, proceeding through task quickly and easily or slowly and with difficulty, understanding model logic and moving into next steps with little assistance, being highly involved or sitting back and letting others do the work,

Challenge
Things to look for: completing the task or nowhere near completing the task, asking questions to expand their understanding or go a step ahead

Questions people ask and general observations

List some examples of questions that you were asked by participants and how many times you were asked throughout the day.
Use the following table:
[NOTE: THE BLANK TABLE HAS BEEN REMOVED TO CONSERVE SPACE IN THIS REPORT]

Your own reflections

[NOTE: THE BLANK TEXT BOXES FOR THE QUESTIONS BELOW HAVE BEEN REMOVED TO CONSERVE SPACE IN THIS REPORT]

What do you think people learnt?

What do you think people found difficult?

How well do you think participants understood the model? What leads you to believe this?

What did you learn?

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