Faculty of Engineering and Information Technology

Agent-Based Modelling for Disaster Management Knowledge Analysis Framework

Dedi Iskandar Inan

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Certificate of Original Authorship

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as part of the collaborative doctoral degree and/or fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

Sydney, November 2017

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Dedi Iskandar Inan

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Abstract

In Disaster Management (DM), reusing knowledge from best practice and past experience is envisaged as the best approach for dealing with disasters. It is important to recognise however that there are no identical disasters. But there are obvious similarities. The challenge is to identify the similarities in the diverse complex characteristics inherently intertwined in the DM knowledge. There are often various autonomous entities: individuals, agencies, organisations, involved in the DM that are coming with their interests, hierarchy structures, resources, and etc., that need to be interacted and communicated with in DM. They have to deal with uncertainty and time-sensitivity as the critical factors otherwise any single situation might lead to the catastrophic.

An authoritative agency typically leads the combat of a disaster. The agency organises and elicits the knowledge subsequently structure it into a sharable and reusable format, the Disaster Management Plan (DISPLAN). DISPLANs are maintained by the authoritative agencies encompassing the Prevention, Preparedness, Response and Recovery (PPRR) phases. In a case of disaster, the DISPLAN will be activated to be accessed by the stakeholders. However, accessing the knowledge out of the DISPLAN is challenging. Knowledge in DISPLANs tends to be structured in a business specification format. Accessing the knowledge can have a subjective element. The fuzziness and the intertwine of knowledge across all PPRR phases in their structure can hinder access in a timely manner.

This dissertation contributes to development of a knowledge transfer analysis framework to unify access to DISPLANS through a unified repository. This framework is developed following Design Science Research (DSR) methodology in Information System (IS). Agent-Based Models (ABMs) are used to code the DISPLANs to enable their transfer into a repository. ABMs enable the representation of many DM characteristics and processes expressed in the DISPLANs. The Object Management Group (OMG) Metamodeling Framework is then used to create a repository that is ready for storing the content of ABMs. The repository itself is underpinned by a metamodel structure that facilitates the retrieval and DM decision making processes in the context of their use. The overall approach is evaluated using DISPLANs from the State Emergency Services (SES) in Australia. The framework is successfully used to analyse and convert the SES DISPLANs into the metamodel based repository. The resultant approach and repository enable better access, sharing and maintenance of the DM knowledge.

Publications

A number of publications as the outcome being produced from this thesis are in peer-reveiwed of an internatioan journal and conferences and a poster presentation.

Conference

- Inan, D. I., Beydoun, G., & Opper, S. (2015). *Towards knowledge sharing in disaster management: An agent oriented knowledge analysis framework*. Paper presented at the Proceedings of the 26th Australasian Conference on Information Systems (ACIS2015), Adelaide, South Australia, and 30th November - 4th December 2015 (ABDC/ACPHIS "A").
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Journal

- Inan, D. I., Beydoun, G., & Opper, S. (2017). *Agent-based knowledge analysis framework in Disaster Management*, Special Issue on Disaster Management and Information Systems: insights for emerging challenges*, Information Systems Frontiers*, pp. 1-20 *(Forthcoming)* (ABDC/ACPHIS "A").

Award

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1 Introduction

Disaster Management (DM) knowledge has long been acknowledged as playing a significant role in reducing the impact caused by disasters. It helps people at the decision-making level to produce contextual decisions, as they are produced from the interaction of the involved social entities and their experiences and those who are on the ground to appropriately react towards the disaster. While DM knowledge is seen as critical, its reuse remains challenging due to its complex structure and availability. This relates to whether the knowledge is structured in a way other people can understand it comprehensively, and its accessibility at any point in the timeline of the disaster management cycle. This thesis contributes to this field by introducing a knowledge analysis framework to improve structuring and reusing DM knowledge in a timely fashion. The aim is that the complex characteristics of the knowledge can be disentangled and subsequently transferred into a representative repository, facilitating sharing and reusing activities.

This chapter sets out the overview to the DM knowledge adoption, the challenges and motivations of this research and its contributions. It also outlines the structures of the rest of the thesis. Section 1.1 provides the background and overview of the research. Section 1.2 discusses challenges and motivation as the drivers in this research. Section 1.3 elaborates the research objectives. Section 1.4 describes the research contributions. Section 1.5 provides an overview of the thesis structure and Section 1.6 concludes the chapter.

1.1 Disaster: An Overview

Researches have shown that disaster events will increase significantly in the future (Kundzewicz *et al.*, 2013), and the most likely causes are the destruction of natural habitat (Hristidis *et al.*, 2010; UNDESA, 2014) and climate change (Cavallo, 2014). Figure 1.1 illustrates the disaster trends reported in the World since the 20th century up to early 21th (CRED, 2015).

Natural disasters cannot be prevented, but they can always be better anticipated and studied. Resultant knowledge can be stored and shared by public and private stakeholders, including emergency management agencies, law and order authorities, to develop their DM endeavours. The more complete the knowledge about a potential disaster, the better the decision-making process becomes (Gulati *et al.*, 2014; Jackson, 2014).

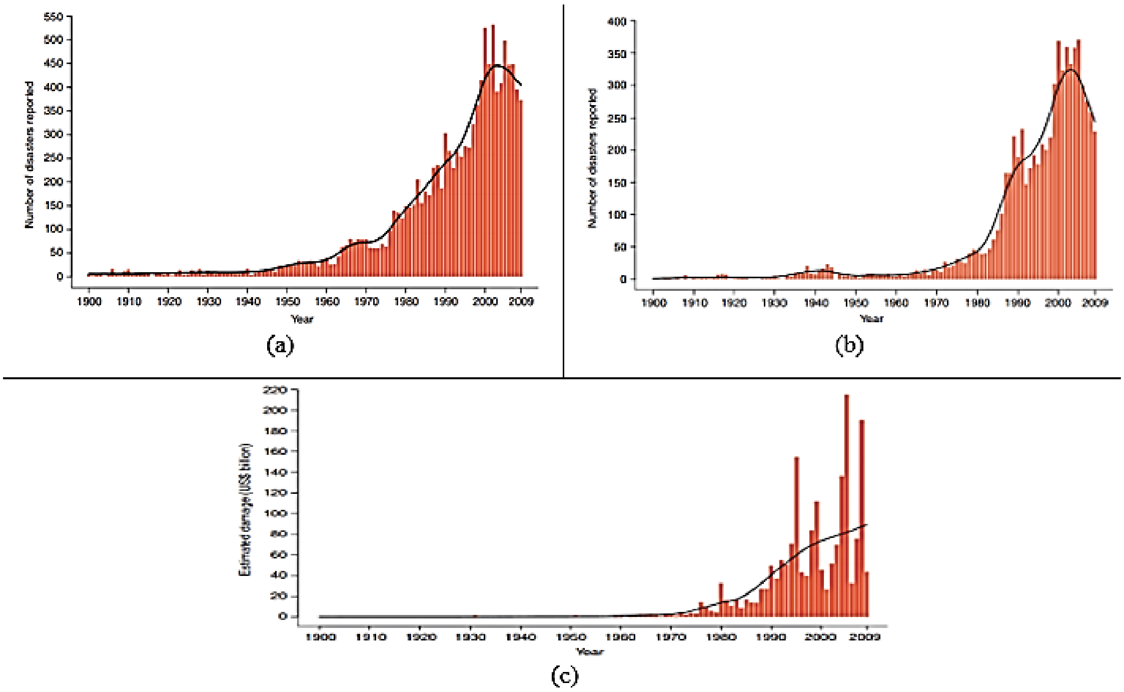


Figure 1.1 Disaster trends: (a) Number of natural disasters; (b) Number of technological disasters; (c) Loss caused by disasters economically, reported in the world.

DM includes attempts to prevent a hazard becoming a disaster and/or attempts to reduce the impact caused by a disaster (UNIDSR, 2015). There has always been a group of people or individuals an ongoing disaster vortex harnessing the extant knowledge to respond effectively and efficiently to various disasters. For instance, people in Simeulue island, Aceh Province (Indonesia), harnessed DM knowledge passed to them from earlier generations (Syafwina, 2014). This knowledge saved almost the entire population of the island compared to the mainland of the province in the Indian ocean mega earthquake followed by the worst tsunami disaster in 2004 (McAdoo *et al.*, 2006). Likewise, in the Japanese Tsunami in 2011, the disaster caused more than 25,000 casualties in the most disaster-aware nation on Earth (Satake, 2014). Nonetheless, in that event, all students in both junior high and elementary schools in the areas affected could manage to escape and save their lives, as they had been prepared with prior knowledge (Parker, 2012). Similarly, this could also be noticed in the Philippines in 2014 that experienced zero casualties as the country put to use knowledge learnt from a previous typhoon disaster, a year earlier which had caused more than 6,300 casualties (UNISDR, 2014b). Other examples of DM knowledge reuse: in 2015 when a cyclone struck Vanuatu, the local indigenous knowledge was extremely useful to save lives there (Minowa, 2015), during drought season in Cameroon people in the country were able to survive as they had learnt from the past (Nfor, 2015). Many other experiences illustrate how harnessing prior knowledge is a determinant factor in saving lives (Hiwasaki *et al.*, 2014b; Rumbach & Foley, 2014; UNIDSR, 2008). The resilience pattern is clear. Learn and embrace prior knowledge to inform action during similar disasters. In the context of

DM, resilience is about two capabilities: (1) a capability of bouncing back from unforeseen stress; (2) capability to adapt to the situation. In other words, the resiliency is determined by the level to which the affected communities have the necessary resources and ability to manage them during the required situation (Fisher, 2015; UNISDR, 2012). Although the knowledge transferred is often in different formats, it remains extremely useful in saving lives. It is not a surprise that developing and maintaining the knowledge management system, encompassing the codification and sharing as well as reusing the knowledge in the DM activities has been ongoing for quite some time (Noran & Bernus, 2011; Pathirage *et al.*, 2012).

Knowledge from the best practises of DM is acknowledged as profoundly effective and efficient (Canton, 2013). It is proven as the critical factor in DM resilience endeavours (Dorasamy *et al.*, 2013). It informs the stakeholders of the tipping points of the DM timeline and how to response appropriately towards them. In a particular disaster, like a flood, knowledge from the best practice is considered as most appropriate one compared to formats generated from simulation activities only (Opper *et al.*, 2010). This is not to say that simulation is less useful in this particular context, since it has a great impact in predicting various situations based on the input assumptions in to the system. Eventually the stakeholders will have a broader understanding of the events based on the output, resulting from the process. However, in the DM domain, the assumptions themselves are inherently uncertain. In other words, each of the possible situations that might occur will impact on the decision-making mechanism to respond appropriately. For example, in an evacuation activity, the "*decision is being made not because what is known but because of what is unknown*" (Opper *et al.*, 2010, p. 180). In recent years, several studies have been devoted to formulating the knowledge transfer mechanism (Adrian *et al.*, 2014; Benaben *et al.*, 2016; Chen *et al.*, 2014; Lauras *et al.*, 2015; Othman & Beydoun, 2016; Ramete *et al.*, 2012). They have all acknowledged that knowledge in DM is inherently complex and likewise, the resultant knowledge structures are complex. This not only impedes the knowledge reuse frameworks. Indeed, the typical knowledge structures are not easy to be understood by the stakeholders. These are the issues driving this research.

This thesis aims to provide a framework by which the DM knowledge can be extracted to facilitate sharing and reusing activities. The focus is in the processes of identifying an appropriate methodology for capturing the complex structure of DM knowledge and for creating a representative repository where the extracted knowledge will be deposited. In combination with the depositing processes, the repository will facilitate the sharing and reusing process. This will contribute to the DM resilience endeavours.

1.2 Challenges and Motivation

A disaster event is unpredictable and uncertain (Ramete *et al.*, 2012). Managing the activities involved can be very challenging and complex (Helbing, 2013). For a given DM activity, there are often many stakeholders involved, both public and private. All stakeholders have their own, possibly important roles. They all have different backgrounds, resources and goals (Wang & Hsiao, 2014); they also have to respond within time constraints. Timeliness of response and action is usually critical in DM scenarios (Janssen *et al.*, 2010). With various stakeholders bringing their own structures and backgrounds, and without appropriate communication channels being in place ahead of time, the timely knowledge exchange between the various stakeholders is severely compromised (Heard *et al.*, 2014). The communication and knowledge-sharing support is critical to enabling negotiation and cooperation.

Currently, the agency leading the program to combat the disaster assumes the role of organising and eliciting the knowledge, and ultimately structuring it in a shareable and reusable format. The knowledge is produced and structured as DM plans that are made available via the web. However, accessing the knowledge specified in a semi-structured natural language format is very challenging (Selway *et al.*, 2015). The written knowledge tends to be structured in a business specification format, which, in fact, is seen as subjective by the stakeholders. Much analysis may be required to enable development of useful and actionable insights. In this thesis, the challenge of DM is harnessing and sharing knowledge between stakeholders who are involved in the timely and effective reduction of the impact caused by a disaster. The first step towards this is to revisit the codification of DM knowledge document sources to facilitate the reuse and sharing of the knowledge they contain.

This thesis presents a framework to facilitate this first step of harnessing the knowledge. The thesis recognises that the existing and widely adopted DM process model, consisting of the four phases of DM—Preparedness, Prevention, Response, Recovery (PPRR)—is typically used to organise DM knowledge (Rogers, 2011). Indeed, various DM activities and knowledge units required throughout the DM processes are organised according to the sequence of these four phases. However, with all the efforts that go into developing them, substantial knowledge about various phases can be scattered throughout the documents and therefore they may not fully adhere to the PPRR process. At the heart of the PPRR itself, a problem lies that is more difficult to correct. With all its prominence in DM activity, PPRR does not actually conceptualise the process of disaster management holistically, rather it does it sequentially (Becken *et al.*, 2014). This feature of PPRR is completely inconsistent with the modern view of aiming to have risk management permeate all DM activities (Crawford *et al.*, 2013).

Numerous entities (individuals/agencies/organizations) that are coming with their own goals representing their interests, structures and backgrounds need to be synchronized in a coordinated activity to pursue a common goal with time and their entities constraints. In the DM resilience endeavours, recognizing holistically the knowledge across all phases of the existing framework is more strategic and efficient instead of replacing it (Rogers, 2011). Inability to recognize and structure the knowledge across all phases from the conceptual to real activities is the issue that needs to be taken account of. In addition, the process of analysing the written knowledge in a complex domain, such as DM, is not only difficult but also time-consuming (Brown *et al.*, 2016)

Linear and sequential descriptions of events are inherently limited. Participants are hindered from engaging beyond the limit of the event timeline. In order to mitigate the risk of introducing errors, sequential modelling was abandoned, for instance, in the software development many years ago (Lopez-Lorca *et al.*, 2015). It is well accepted that software practitioners typically engage in iterative thinking and problem-solving, moving up and down multiple abstraction layers. Applying this same paradigm and insights to representing DM processes, a multi-layered metamodeling approach which follows the Meta Object Facility (MOF) approach (OMG, 2013) is proposed. As a first knowledge analysis step to enable this, the thesis proposes an approach based on Agent-Oriented Analysis (AOA) to appropriately codify DM knowledge.

Particularly in the DM domain, the use of AOA for knowledge codification is with the fact that the paradigm is capable to cover a set of various and intertwined tasks (e.g. interaction, communication) and actors (e.g. communities, emergency services, polices) with conditions as constraints as to comply with given the possible inflicted consequences. This is not to mention the uncertainty factor as the nature inherently in the DM. In DM activities, what is meant by this latter characteristic is that anytime something might happen, in particular, in an event by which nothing that can control over it (Blackman *et al.*, 2017). As such, what can be done in dealing in this situation is that a set of course of action should be available at the first place to mitigate the bigger impacts triggered by the time element (Dorasamy *et al.*, 2017; Horita *et al.*, 2017). Compared to other paradigms, for example object-oriented or procedural, this is essentially the distinguished factor of agent-based paradigm in which employed models in the analysis stages are capable of (Ashamalla *et al.*, 2017).

In the DM, the knowledge structured in the document plans/Disaster Management Plans (DISPLANs) does not articulate a single goal. Entities involved in a DM activity need to not only react or adapt to the environment, but also to exhibit their local goal formulation (Doyle *et al.*, 2014). The ability of each entity to recognise the relevant DM knowledge (Dominey-Howes *et al.*, 2014) is urgently required. Critical environment characteristics cannot be controlled and predicted, but awareness of them is essential to facilitate cooperation (Hiwasaki *et al.*, 2014b; Rumbach & Foley, 2014). Entities/organisations/individuals involved have their own goals, resources and structures in which, at the same time, the need to communicate and negotiate to pursue common goals is paramount. Identifying the goals of the DM activities of other entities is crucial (Hawe *et al.*, 2012). This will require those others to be involved. To enable all this, there is an imperative for timely sharing and re-using of knowledge.

For the depositing process, this thesis advocates the use of a knowledge repository based on a common MOF modelling framework, the Object Management Group (OMG) (OMG, 2013), and a Disaster Management Metamodel (DMM) (Othman *et al.*, 2014). The DMM was originally developed following the use of a MOF rigorous methodology to represent the DM domain according to the three modelling layers advocated in the work of (Atkinson & Kuhne, 2003; Daniel & Matera, 2014): *M0* (real world objects), *M1* (model) and *M2* (modelling language/metamodel). Specifically, the thesis addresses the challenge of how to convert existing DM knowledge into layers of abstraction. This enables abandoning a timeline sequence in favour of free flow access to any point. The proposed approach converts end user models to concepts and notation from the DMM, and relies on AOA to achieve this. This approach addresses the interoperability of the converting processes by following the MOF framework. Agent-Oriented (AO) models lend themselves to representing organisational know-how and DM processes. They emphasise the constructs of roles, agents and organisations to represent systems' behaviours. With appropriate supporting tools, this knowledge can be deposited and shared using a DMM-based repository.

1.3 Research Objective

As implied in the previous section, the Agent-Based Model (ABM)[1] from Agent-Oriented Software Engineering (AOSE) is recognized as having capabilities in representing complex domains (Jennings & Wooldridge, 2001; Wooldridge & Ciancarini, 2001), in particular the organisational know-how of the DM. However, identifying best analyses and structuring processes associated with AOA is a challenging task in DM. This is due to the fact the there are many ABMs proposed by various methodologies in this domain (Argente *et al.*, 2011). In addition, the adopted ABMs have to be capable of representing the knowledge in detail as a basis on how a decision will be made in any particular event. The MOF framework will be adopted in this research to disentangle the fuzziness and interwoven DM concepts. It will play a foundational

[1] Agent-Based Model (ABM) and Agent-Oriented Model (AOM) refer to the same thing and might be used interchangeably in this thesis.

role in the knowledge transfer mechanism. The overall analysis process needs to ensure that MOF can be tailored together with the knowledge structures in ABM formats.

To facilitate this knowledge transfer process, at one end, the knowledge is analysed and modelled based on each of the representative ABMs. At the other end, the DMM-based repository also needs to be prepared. Through these processes, the ABMs representing the knowledge of the domain are deposited into the representative repository. Whilst DMM and the ABM employed in this research are both usable DM, they are developed in different paradigms with respect to Model-Driven Development (MDD) (Atkinson & Kuhne, 2003). Once the repository is prepared, the transferring processes of ABMs to it can be undertaken. Eventually, this will facilitate and accelerate the decision-making process in the DM activities. Towards this goal, the objectives of this research are formulated, as follows:

1. Identifying and inventorying the ABMs in Agent-Oriented Software Engineering (AOSE) which can be employed to capture and reflect all the concepts and details of the DM knowledge.
2. Conducting AOA of semi-structured DISPLAN knowledge documents and structuring them into identified ABMs which reflect DM knowledge in detail. The result of the process is ABMs of DISPLAN knowledge which can be transformed to the later development phases.
3. Introducing the MOF framework to disentangle the fuzziness and interwoven knowledge in the DM domain. This approach will be tightly coupled with the ABMs by structuring the models into their logic layers before transferring them into the repository.
4. Coupling DMM with MOF as the format of the representative repository where analysed and modelled AB knowledge models will be deposited. This identified repository format should be made compatible with the knowledge formats structured in the AB models. In addition, the repository should also recognize the knowledge from any type of DM. This is along with the validated DMM (Othman *et al.*, 2014) adopted in this research that is representative for any DM type.
5. Demonstrating the transferring process of AB knowledge models to its DMM-based repository facilitating the sharing and reusing in the decision-making processes.
6. Developing a tool as a proof-of-concept. The tool will be the user-friendly interface, particularly for the non-technical users to enable them understanding the technical details. It will process all objectives described in this proposed research.
7. Demonstrating that the holistic decision making process using retrieval mechanisms from the representative repository.

In conducting the research, there are some notes that need to be highlighted in terms of clarifying its objectives. These will not be pursued, as they are outside the scope of the research as follows:

1. This thesis will not discuss the DMM development process. As discussed in the previous section, the DMM adopted in the thesis is well developed and structured from a previous work (Othman *et al.*, 2014). The DMM is used as a representative repository in this thesis. The detail justification will be discussed in the next chapter.
2. This thesis will not discuss Multi-Agent Systems (MAS). Although ABMs adopted in this thesis are originally developed for the purpose of being used in the development of MAS, this thesis is not intended to develop MAS software. In contrast, the objective of the thesis is to specify a requirement analysis based on ABMs, as it will be applied in the DM as a complex domain. In conducting the research, the ABM paradigm is adopted to extract the characteristics and details of complex knowledge of that particular domain.
3. The process of transferring the AB knowledge models into the repository will be semi-automatic. This thesis proposes a new approach to how DISPLAN knowledge in a semi-structured format is deposited in a representative repository facilitating the sharing and reusing processes. A primary goal of this thesis is to exhibit how the framework is developed and works as intended. Therefore, a human intervention mediates the transfer process.

1.4 Research Contribution

This thesis produces a framework to facilitate the knowledge analysis in the DM domain. Several novel concepts are part of artefacts composing the framework development, including a prototype system. The contribution of the thesis is elaborated as follows:

1. The ABMs are considered and adopted in analysing and modelling the various complex domains. The ABMs also have been recognized in the DM domain but to create simulations. However, none of the scholars in the literature employs the ABMs in requirement specification of the DM domain to extract the knowledge out of this complex domain. This thesis contributes in justifying that ABMs are the most suitable method to be used in analysing and modelling the DM domain to be able to extract the knowledge. This is followed by structuring the knowledge in a way so that it can be used in later development phases.
2. As part of the objectives of the thesis, this study addresses the issues related to the fuzzy and interwoven nature of DM knowledge. This thesis contributes in adopting the MOF framework to improve the DM knowledge structure into layers representing the conceptual, policy and

real world activity levels. This will enable the DM stakeholders to easily identify the relevant knowledge at reuse time facilitating a better decision support system.

3. In the DM resilience endeavours, this thesis contributes in justifying the use of DMM as a representative repository for sharing and reusing the knowledge. The DMM-based repository is structured representing the complete DM constructs, phases and layers. This repository is used as an accessible DM knowledge repository, where related knowledge can be stored, adopted, and adjusted for any particular purpose.

In summary, this thesis contributes in the DM resilience endeavours by proposing a new approach to how to convert the knowledge structured in a semi-structured format to the DMM-based repository. The novel feature of the proposed approach is that this framework can be applied to any type of disaster. In addition, the written semi-structured knowledge is the input to the framework; as such it can be processed by any DM practitioner even one who does not have a computer-skilled background.

1.5 Thesis structure

This thesis is organized into eight chapters, outlined here as follows:

- **Chapter 1 Introduction**. This chapter overviews challenges, motivations and objectives that lay down the research contribution of the research.
- **Chapter 2 Literature Review**. This chapter reviews the relevant and existing concepts which underpin this research. In this thesis, agent-oriented paradigm is reviewed for its capability to represent the complex knowledge characteristics out of that particular domain and metamodel structures as the most representative repository where the analysed knowledge can be stored. This is subsequently concluded with a summary of limitations of the existing approaches as a gap in which this research is aimed to contribute to.
- **Chapter 3 – Research Design**. This chapter overviews how the research is framed in a rigorous methodology adopted in this thesis, the Design Science Research (DSR). It also prescribes the research stages and how they will be conducted as well as the evaluation procedures.
- **Chapter 4 – Knowledge Analysis Framework Development**. This chapter describes the development stages of knowledge analysis framework. In Information System (IS) design research, this is essentially the artefact built based on the DSR methodology. This chapter presents the prescription as to how to construct the artefact for addressing the gap identified in the literature review. The development stages of the artefact are shown in details. As this still requires extensive refinement and validation, it is construed as the initial version.

- **Chapter 5 – The 1st Framework Evaluation**. This chapter essentially evaluates whether the developed framework works as intended. This is conducted by validating it through a case study. A tool which is developed in this research for the validation processes to evaluate the developed artefact. The evaluation in this chapter is conducted covering four dimensions: functionality, user, tool and domain. In particular, this validation type is aimed to evaluate each step of the developed framework and uncover any omissions or errors inadvertently introduced, before externally evaluating the framework. The process is carried out iteratively and any refinement resulting from this stage will provide feedback to improve the framework in subsequent evaluations.
- **Chapter 6 – The 2nd Framework Evaluation.** The evaluation in this stage is based on the feedback resulted from the first evaluation. The aim is to omit the discrepancies between the developed framework and the research objective. The feedback resulted in the second evaluation will be the basis to re-improve the framework which subsequently needs to be re-evaluated. Another case study will be set for this evaluation.
- **Chapter 7 – The 3rd Framework Evaluation**. All the feedbacks from the previous evaluation are incorporated to improve the framework. The framework undergoes another validation with another case study to measure its effectiveness. All the dimensions as in the previous evaluations are also validated through this particular case study in which the aim is to examine whether the framework works as it is meant to work.
- **Chapter 8 – Conclusion**. This thesis is summarized by outlining the findings, drawing the conclusion and pointing out the limitations of the study. The future work for thesis extension possibilities will also be laid out in this chapter.

1.6 Chapter Summary

This chapter begins by overviewing the domain on which the thesis will be focused. The challenges and motivation factors are justified in the research. The research objective and its knowledge contribution which has resulted in this thesis are highlighted. A more detailed literature reviews and the justification of the adopted methods will be presented in the next chapter, particularly the method to extract the knowledge from the DM domain and the representative repository for depositing the knowledge.

2 Literature Review

In this chapter, the existing and related works underpinning this research are presented. Generally, they are the related concepts enabling the knowledge transfer mechanism, particularly in the DM domain. In the transfer process, the components that must be in place to allow this to happen are input, output and knowledge analyses per se. Through this process, the ultimate goal is to effectively and efficiently enable the knowledge to be reused by others in responding to the typical DM disasters. In order to achieve this, the complex DM knowledge is taken as the input in a semi-structured format to be analysed. This is aimed to decompose the complexities of the knowledge prior to taking it into the transformation process. The Agent-Based (AB) modelling from Agent-Oriented Software Engineering (AOSE) methodology is employed to examine this task. The output resulting from this activity is then deposited into a representative repository to allow the sharing activities and to enable it to be reused for a comprehensive decision making mechanism.

In this chapter, these components are elaborated on in the following sections: Section 2.1 presents the natural characteristics of the disaster domain. All the complex characteristics of the DM domain are elaborated on prior to justification of an appropriate methodology for analysing and extracting them. Section 2.2 reviews the challenges in representing those characteristics to allow them to be taken into a further development process. Section 2.3 examines a representative methodology to be adopted, that is the modelling activity based on the AOSE paradigm. Section 2.4 examines the issues regarding the knowledge structure to disentangle the complexities, allowing it to be transferred into a representative repository. Section 2.5 discusses and reviews the knowledge transfer mechanism per se and finally, Section 2.6 summarises this chapter.

2.1 Disaster Management: A complex system perspective

Dealing with disasters is a profoundly challenging task. It has to be sensitive to time, dynamicity of the environments and situations that change rapidly. It involves independent entities which need to be synchronised to react and to be proactive when there are changes of circumstance (Rolland *et al.*, 2010; Zobel & Khansa, 2014). The DM becomes even more challenging when the activities occasionally have incomplete information (Carver & Turoff, 2007). Given the consequences of disaster, natural and/or man-made (i.e. loss of properties and human life), supporting DM with better information and knowledge access is urgently required (Sautter *et al.*, 2014; UNDESA, 2014). It is worth noting that the terms disaster, crisis and emergency are often used interchangeably. They all refer to a large-scale catastrophic disruption beyond human's capacity (Boin & Hart, 2010; UNISDR, 2009).

As the disaster is uncertain and unpredictable (Scerri *et al.*, 2012a; Wex *et al.*, 2012), not only are there rapid changes of the environment, but also disasters might strike at very short notice (Berryman & Campbell, 2010). In other words, the variables which lead to a particular disaster cannot be foreseen. Unpredictable factors are actually inherent to DM (Cavallo, 2014). The uncertainties and unpredictability are key features of a complex system as echoed in Flach (2012) that "*a system is complex if its future is uncertain*" (p. 188). Polack *et al*. (2008) define that "*space, time and environmental context*" (p. 482) are among the features of complex systems. In addition, a complex system itself has been emerging and is being described in multidisciplinary researches (Berryman & Campbell, 2010; Katina *et al.*, 2014a; Keating, 2009).

Recently, various scholars have been describing the DM as a complex system (Katina *et al.*, 2014b; Wang & Hsiao, 2014). Cavallo and Ireland (2014) for instance, point out that this is characterised by many and various entities involved in the activities. Janssen et al. (2010) assert that since multiple organisations are involved in a DM activity, they have to be time-sensitive as the consequence of their actions can lead to fatalities, loss of properties, and catastrophes. In addition, the multi-organisation involvement naturally will impede achieving the main objective as these entities come with their own goals and interests. These goals and interests are interdependence (Flach, 2012) and if these occur over time with the high degree of complexity, the consequence is that the states "*are more uncertain or are more variable*" (p. 189). A systematic understanding of those complex knowledge characteristics is critical for a DM to be more effectively and efficiently managed (Cheema *et al.*, 2016).

To be able to achieve this, these complex characteristics are required to be structured and presented comprehensively and holistically. The DM knowledge needs to be extracted and structured. This is strongly motivated by the fact that the DM knowledge needs to be shared and reused by others to respond to the typical disasters in Disaster Risk Reduction (DRR) endeavours (UNISDR, 2014a). The DRR itself is a systematically global effort by DM stakeholders: government, organisation and civil societies, to manage the causal factor of disasters through a plan prepared the authoritative (UNISDR, 2009). A case in point of the plan is the Hyogo (UNISDR, 2005) and Sendai Framework (UNIDSR, 2015) being coordinated by United Nation International Strategy for Disaster Reduction (UNIDSR) as a guidance to be adopted by world communities to combat the disasters. In the next subsections, these inherent complex characteristics in the DM domain are presented and examined. This provides an insight into how the DM knowledge contributes to develop the DM resiliency endeavours.

2.1.1 Situatedness in an environment

The situatedness in this context refers to the capability of agents in a DM activity to respond with appropriate actions as they are able to discern the environmental changes (Jennings & Wooldridge, 2001; Wooldridge *et al.*, 2000). As DM involves many agencies/organisations, communities, volunteers and individuals (Jackson, 2014), all these entities affect and perceive the dynamic environments (Winikoff & Padgham, 2013). The fluctuating environments are the distinguishing factors between complex and linear systems (Wooldridge & Ciancarini, 2001). Each of these entities has its own goals, roles, scenarios, resources and many more characteristics. These all need to be synchronised to achieve a common goal, a DM resiliency. Therefore, to allow this to happen, those knowledge characteristics should be analysed and structured to be effectively and efficiently managed (Leskens *et al.*, 2014). This is drawn in Figure 2.1. While there are no identical disasters (Coppola, 2011), this leads to the consequence that there is no generic formulation to be adopted in every single DM instance. All the knowledge for the decision-making activities has to take each of these unique environments into account.

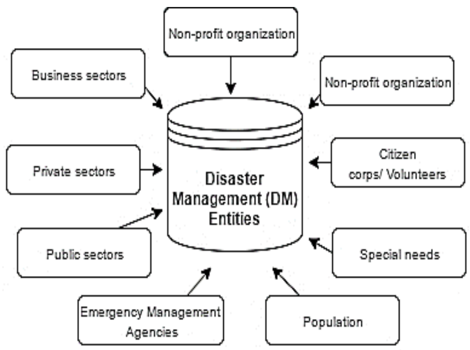


Figure 2.1 Entities in a Disaster Management (adapted from (Cavallo & Ireland, 2014)).

As discussed previously, in every single disaster, the situations are very dynamic (Bharosa *et al.*, 2012), for instance, in a flood disaster, the water level of levees, a river, or inundation keeps altering. On the other hand, the decision-making processes should be based on these ongoing situations with respect to the information from available and trusted knowledge resources (Khawaja *et al.*, 2014). This is considered as a critical factor in terms of developing the best practice scenarios, as each of them presents various consequences in the decision-making process. Even in every minor variation, the DM knowledge will automatically have to be re-managed and re-dealt with. They have to recognize the roles that each of them should play and the responsibilities that each of those roles should comply with. Moreover, they should be aware of which organisation/agencies should be contacted to communicate, negotiate and synchronise the response to the DM activities accordingly in advance. For an effective and efficient DM, all these typical knowledge elements should be identified and laid out in the first place. All these typical concepts need to be shaped diligently in a comprehensive scenario to respond to the situations appropriately. In fact, the awareness of these typical circumstances should also apply to other knowledge elements, for instance, relevant resources required to respond to a particular event (García-Magariño & Gutiérrez, 2013; Scerri *et al.*, 2012a).

2.1.2 Time Sensitivity

Another significant aspect of a disaster is being time-sensitive, which can lead to losses when the response is too slow or does not occur in time (Coppola, 2011). Doyle *at al.* (2014, p. 7) show that in DM activities, time-related factors: "*timing, intensity, duration etc.*" are extremely urgent. These are highlighted as challenging issues that should be addressed in DM research. In fact, the inability to understand appropriately time management in a DM leads to fatalities (Drupsteen & Hasle, 2014). This factor contributes to a form of complexity as it involves interlinking of different knowledge sources in the domain of *time, space and people* (Vitoriano *et al.*, 2013), and in both pre- and post-disasters (Sharma *et al.*, 2015). Figure 2.2 shows that a sensitivity to time in DM resilience endeavours is urgently required.

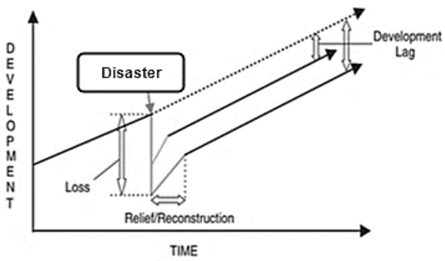


Figure 2.2 Time-sensitivity impacted to disaster development (adapted from (Coppola, 2011)).

In this research, the time sensitivity is seen as capability of an agent reacting and pro-acting in time with appropriate actions to develop the resiliency, that is bouncing back after the stress of adapting to a particular disaster event. A more effective response to the situation in a disaster occurrence means only a little time is needed to bounce back by conducting response activities as soon as possible, using available and comprehensive DM knowledge. A case in point is in the 2011 Fukushima Disaster event: Daiichi and Daini nuclear power plants disaster in Japan (Gulati *et al.*, 2014). In that disaster, the decisions made in a timely manner with adequate knowledge was proven to save a more disastrous impact of the nuclear melt down.

That technological disaster showed that timely response combined with comprehensive DM knowledge are the elements that must be developed and be in place in order to respond to the disaster. Since a disaster's characteristics are uncertain and unpredictable, any failure to understand time management issues will be hazardous and which might lead to a catastrophe. That particular case showed that it was a disaster (tsunami) which occurred driven by a natural one, an earthquake. These typical occurrences are event-driven (Rich *et al.*, 2013) as almost 9.0 magnitude of the earthquake, followed by 6m high tsunami waves drove the nuclear meltdown of those two reactors. This can also be observed in other disasters in the world; for instance, the Indian Ocean tsunami was driven by a 9.2 magnitude earthquake in 2004 (Cavallo, 2014). In such typical disasters, the event-driven patterns are likely to occur where no one is able to control the occurrences, as shown in Figure 2.3. This figure illustrates that "*time is everything*" (Janssen *et al.*, 2010, p. 2). In other words, in an imminent event, unable to be time-sensitive can lead to a worse situation. Therefore, in the context of the DRR, recognizing this typical characteristic is extremely important yet challenging.

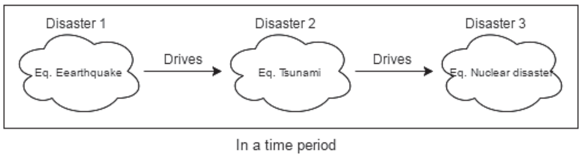


Figure 2.3 Disaster, as an event-driven catastrophe, has to be managed over time (Adapted from (Cavallo & Ireland, 2012)).

2.1.3 Non-deterministic

In a DM activity, all the activities have to deal with the rapid change of the environment given the consequences that might occur (Wex *et al.*, 2014). The capability to identify factors contributing to the complexities of the DM is critical, on the one hand. On the other hand, as the nature of the disaster is a non-deterministic event, there are various characteristics that might also potentially be present in the disaster occurrences (Scerri *et al.*, 2012b).

In this context, there is a growing body of literature identifying important characteristics involved in the DM (Dominey-Howes *et al.*, 2014; Hiwasaki *et al.*, 2014a; Rumbach & Foley, 2014). These works attempt to utilize information technology enhancement to identify the characteristics (Heard *et al.*, 2014; Shah *et al.*, 2013; Yang *et al.*, 2013). In particular, they adopt modelling and simulation techniques to reveal and recognise those particular knowledge characteristics of the domain. For instance, Scerri, *et al.* (2012a) employ AO modelling to simulate scenarios in a disaster, particularly on how individuals behave towards each other during event. Their research reveals that the simulation approach can be very beneficial in simulating the inter-relationships in a DM activity. By adopting this sophisticated modelling tool based on the AO paradigm, knowledge flow can be managed and delivered efficiently and effectively among the stakeholders.

The prominence of AO paradigm in simulating complex scenarios can also be observed in other scholarly works. For instance, they can be seen in profiling military training tasks (Shvartsman & Taveter, 2014), developing simulation framework for understanding crisis response comprehensively in a natural disaster (Balasubramanian *et al.*, 2006), simulating crowd movement featuring Geographical Information System (GIS) to determine the best patch of ground to move to during flood disaster. These examples show that the AO paradigm is perceivable as a state-of-the-art tool that can be used to define that particular complex and uncertain process. Those researches successfully show that simulations utilizing AO modelling is capable of recognising the complex characteristics of the domain being simulated. Nevertheless, these approaches only simulate a particular scenario that might be occurring. In other words, this approach is limited only to what can be foreseeable (Alférez & Pelechano, 2012). In fact, the nature of the disaster is undeterminable. The variables of the input in the modelling and simulation processes are uncertain. This means the scenarios might or might not be the actual ones representing the real world disaster (Shvartsman *et al.*, 2010). Therefore, equipping the analysis process with an appropriate tool which is able to recognise and cope with this particular characteristic is extremely urgent.

2.1.4 Presence of Autonomous Entities

As indicated previously, managing a disaster involves many stakeholders. They tend to have different roles and responsibilities. This is illustrated in Figure 2.4. Each stakeholders is often an autonomous entities with its own goals and own resources. This implies that each of them is likely to perceive the situations in different ways. Notwithstanding this, DM is also a collaborative endeavour. Those autonomous entities have to be effectively and efficiently arranged to be able to achieve a common goal (Allen *et al.*, 2014).

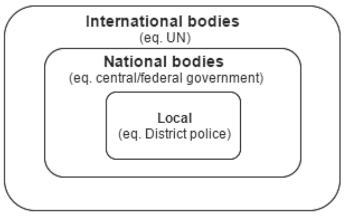


Figure 2.4 Hierarchy level of autonomous entity in DM (adapted from (Cavallo, 2014)).

The collaboration, coordination as well as the negotiation of the involved agencies need to be integrated and synchronised to accomplish a main objective (Aldunce *et al.*, 2016). Janssen *et al.* (2010) argue that all entities involved must cooperate as DM is a complex socio-technical process. They conclude that DM performance can only be optimised by acknowledging the social, technological aspects as well as various subsystems interconnecting them. They then argue that the DM "*is centred around humans, including first responders and decision-makers*" (Janssen *et al.*, 2010, p. 4). Efficiency can be achieved by developing a collaboration among all entities to work together effectively to achieve the common objective(s) (Robinson & Gaddis, 2012).

All entities involved in DM need to share information of emerging situations, resource allocations, activities being pursued and to respond to conditions to manage the operation well (Bharosa *et al.*, 2010). This typical and interdependent collaboration is urgent in all DM activities (Pedraza-Martinez, 2013) to comply with time pressures, uncertainty and unpredictability (Bronkhorst, 2015). In a routine situation, scheduled activities and a strict hierarchy might work well. However, in a dynamic and high-pressure circumstance, those procedural activities often fail (Janssen *et al.*, 2010). As such, to minimise this, every single entity involved in the activities is required to work together, while at the same time each of them has to be aware of its responsibility, resources, task and constraint, as well as share all the relevant knowledge among themselves for a better interaction (Eide *et al.*, 2012). Well recognizing these characteristics underpins success of DM activities (Robinson & Gaddis, 2012).

2.1.5 Reactive and Proactive

In a DM, agents need to be both reactive and proactive. Reactivity refers to the characteristic in which an involved entity senses the environment and reacts towards it, and proactivity is when one of the entities involved exhibits its anticipatory goals and plans (Tveiten *et al.*, 2012). Both characteristics require entities to be able to respond to any changing environment and, at the same time, show they have their own objectives to strive for. A requirement that should be taken into account by those entities is a situational awareness (Ernstsen & Villanger, 2014). This refers to how an individual perceives events and parameters of the environment. By being aware in a case of imminent disaster, an entity cannot only rely on reactiveness, but it should also have to take an initiative to pro-act properly to interpret a particular situation. In this case, this implies the responsibilities of each entity should be articulated as a guide to follow. Particularly in the event where disaster strikes in a very short period of time, the situation could quickly become chaotic, but entities are equipped with comprehensive guidance would be able to react and pro-act accordingly. This is illustrated in Figure 2.5.

Examples to show that reactiveness and proactiveness are critical are the 9.2 magnitude mega earthquake followed by the Indian Ocean tsunami in 2004 that hit Aceh Province in Indonesia and in Japan and the subsequent Fukushima nuclear meltdown disaster 2011 (Funabashi & Kitazawa, 2012). These two cases clearly show those characteristics are critical in preventing casualties. In the Indian Ocean tsunami, the earthquake drove a more than 10m high tsunami that hit the island in less than 10 minutes. The civilians who lived on Simeulue island reacted reasonably to the earthquake and took initiative immediately to flee to the highest place to survive. Their actions are based on the existing knowledge from previous generations as a guidance. As a result, the death ratio of those who lived on the island that is only 40 KM from the epicentre toward their total population are very low compared to the Aceh mainland that is more than five times farther away (McAdoo *et al.*, 2006).

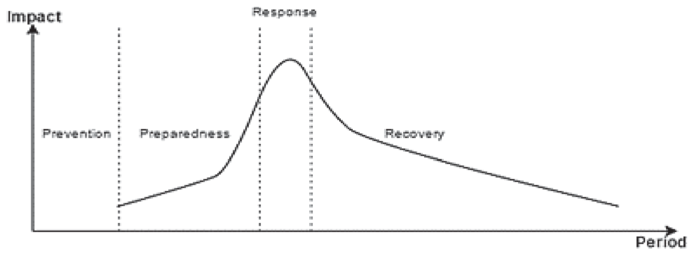


Figure 2.5 Disaster impact across time (Adapted from (Janssen *et al.*, 2010)).

Likewise, in the 2011 Japan earthquake disaster (Hiwasaki *et al.*, 2014b), once the tsunami early warning was issued, all junior high schools students assembled into small groups to react by perceiving the alarm and pro-act towards it to find as high a place as possible to survive. These actions naturally are exhibited by them as they have prior knowledge and the actions are frequently rehearsed in their schools as a wise way to respond to this typical disaster. As a matter of fact, in that particular event, their reactiveness and proactiveness were effective as they all survived, while others did not. With respect to entities' behaviour in responding to a particular situation, they did not necessarily have to wait to respond or react to the situation (John *et al.*, 2008) but most importantly is that they are proactive and taking initiative (Ley *et al.*, 2012) in such disastrous situations. By contrast, for those who did not have knowledge in place, there was no guidance for them to be reactive and proactive following the warnings. These are probably considered as the most notable lessons. Therefore, lifesaving knowledge need to be recognized and structured to developed DM resilience endeavours.

2.1.6 Need for Cooperation

In DM activities, even though the involved entities often represent individuals, they are fundamentally social entities. As such for the DM effectivity, they need to cooperate with each other to share common understandings. In other words all those involved individuals have to be seen as interdependent entities (Steelman & McCaffrey, 2013). In many particular circumstances, they need to be represented in one ad-hock body to be able to interact and negotiate more effectively and efficiently with others. For instance, in a flood disaster event, based on the request of a controller agency, each of the identified entities responsible for DM activities needs to provide a liaison officer to a designated operation centre (SES NSW Australia, 2010). Each of them should have capabilities to be able to speak on behalf of its agency. This is with the aim to have an efficient and effective decision making mechanism (Noran & Bernus, 2011). As such, each of these entities should have a set of protocols to allow them to detach from and re-attach to its organisation, respectively (Hagen *et al.*, 2013).

The cooperation between the entities allows them to not only share and exchange the best practice knowledge, but also to communicate and negotiate for the resource and risk sharing (European Commission, 2011). The entities can become more effective and efficient responders (Cooper, 2013), as they communicate and cooperate (Tatham *et al.*, 2017). This posits that they are able to interact to manage "*transfer, receipt and integration of knowledge across participants*" (Weber & Khademian, 2008, p. 334). Therefore, cooperation and coordination among them are mandatory to work in an effective way (Chen *et al.*, 2008; Netten & Someren, 2011). As such, recognizing this characteristic is not only challenging but also requiring of a more comprehensive and insightful analysis (Ley *et al.*, 2014; McMaster & Baber, 2012; Salmon *et al.*, 2011).

2.2 Representing DM Knowledge

Having discussed the complex characteristics in the DM domain in Section 2.1, the next challenge is to provide appropriate formats to be understood effectively and efficiently. In this section, the challenges and significances of representing those complex characteristics raised in previous section are discussed.

2.2.1 The significance of DM context

To respond to the representation challenges, the knowledge from the best practices is taken into consideration as a representative example. A case in point is the Indigenous Knowledge (IK) embraced in effective and efficient DM resilience endeavours (Kniveton *et al.*, 2015). The typical knowledge is employed by various communities around the world to save as many lives and properties as possible in diverse disaster events. This knowledge is a critical factor to respond accordingly (Nguyen *et al.*, 2014).

The IK itself refers to the "*methods and practices developed by a group of people from an advanced understanding of the local environment, which has formed over numerous generations of habitation*" (UNIDSR, 2008). The IK is the typical knowledge that might be elicited during preliterate eras for a particular purpose (Rumbach & Foley, 2014) and harnessed by communities around the world has been proven effective and efficient in saving lives. The adoption of IK per se has been recognized and institutionalized internationally (Hiwasaki *et al.*, 2014b). While the knowledge is critical in DM activities, formulating and organising it into a sharable and reusable format is extremely challenging (Ton *et al.*, 2016). This relates to the fact that this knowledge type mostly is structured in free and various formats. For instance, this knowledge type has existed in poetry, songs, and tacit (Alexander *et al.*, 2011; Becker *et al.*, 2008; Green & Raygorodetsky, 2010). Therefore, this might be biased, fuzzy and incomplete as it is passed from one generation to another over a long time (Syafwina, 2014). These typical structures impede it being formally adopted (Mejri & Pesaro, 2015).

It is worth noting that knowledge is different from data and information as stated as "*knowledge is information possessed in the mind of individuals: it is personalized information (which may or may not be new, unique, useful or accurate) related to facts, procedures, concepts, interpretations, ideas, observations and judgement*" (Alavi & Leidner, 2001, p. 109). In other words, the knowledge can only be useful to humans if it has resulted from data and information processing.

The fact that the DM knowledge is scattered hinders it being identified (Walshe & Nunn, 2012). In addition to this, in the DM domain, knowledge representation tasks become far more challenging as the knowledge itself deals with various constraints: environmental situation, time-sensitivity, autonomy, non-deterministic and social interactions in which they are all very dynamic. In this context, disentangling the knowledge out of those complexities prior to representing it in a readable way for both humans and machines is critical. In the context of this study, the aim is to disentangle all the complexities and intertwining of the knowledge leading to a better understanding of the decision-making process in DM resilience endeavours.

While the knowledge representation has long been recognised as a crucial one particularly in an organisation (Drupsteen & Hasle, 2014; Nonaka, 1994), this study aims to contribute to this growing research. This is conducted by exploring not only the analysing approach but also the knowledge representation in a comprehensive way for which it can be holistically understood by others, particularly in DM domain context. Typically, the knowledge to be shared is a set of capabilities, know-hows, ideas, information, feedbacks and processes (Oliveira *et al.*, 2014). Occasionally, they are stored in and derived from, for example, documents, processes, routines, activities and norms. (Adrian *et al.*, 2012; Xing-Ling & Xue-Lian, 2012). Thus, once those are shared to be reused by others, the value of those others will also be improved in these ways as they can learn from the existing and best practice ones (Ghobadi, 2014). As such, the way they are formulated and represented will determine how the problem is understood (Aurum *et al.*, 2008; Guzmán *et al.*, 2013). In particular, they can synchronize and adapt the knowledge to their circumstances without analysing it from scratch. In addition, they can also improve and adapt the knowledge based on their needs and constraints (Chandrasegaran *et al.*, 2013).

2.2.2 Reflections towards a systematic DM knowledge analysis procedure

The significance of the knowledge in the DM activities is clear. Therefore, DM knowledge needs a systematic engineering method so that it can be transferred into later development phases (for reuse eventually). As earlier stated, the DM knowledge elements are intertwined, fuzzy and mostly incomplete and this hinders its management and often its timely access. Not surprisingly, DM knowledge engineering has been a continuing concern (Beydoun *et al.*, 2013b; Beydoun & Hoffmann, 2000,2001; Beydoun *et al.*, 2011; Sriram, 1997; Studer *et al.*, 1998). The challenge is that while the knowledge is abstract in nature (Ghaffar *et al.*, 2012), the effectiveness of its representation depends on the effectiveness of the abstract concepts used to describe a domain (Beydoun *et al.*, 2011). Many scholars embrace the incremental heuristics techniques of knowledge acquisition to encode the knowledge based on "IF-THEN" rules (Beydoun & Hoffmann, 2001). They implement this approach in various fields, for instance, in an expert system using machine learning (Li *et al.*, 2013), incremental acquisition (Beydoun *et al.*, 2010), neural network architecture techniques (Hinton *et al.*, 2014). However, these approaches cannot be built encompassing all facts and in a single stage.

There is a common understanding that knowledge is the result of a deductive process of the available information (Beydoun & Hoffmann, 2001; Ghaffar *et al.*, 2011). Crawford *et al.* (2009) articulate this further that "…*knowledge, on the other hand, can be distinguished as the human capability to interpret information and use it creatively, both individually and cooperatively, to add value to human activities and products"* (p. 3). This implies that in a knowledge representation, context awareness matters. It depends on the human capability for interpreting. In other words, this effort to extract the knowledge characteristics out of a domain depends on heterogeneous situations and conditions of that particular domain. This task becomes more challenging as it has to take into account any subjective variable affiliated with the domain. The necessity of an appropriate methodology that is able to deal with these circumstances is critical. In other words, the DM knowledge can rely on rules and procedures (Smits *et al.*, 2009; Xu *et al.*, 2013) so that, it can be meaningful to users (Davis *et al.*, 1993), as echoed in *"…information can be used only when there is a procedure for extracting it*" (Markman, 2013, p. 10).

In general, knowledge analysis and modelling are activities aiming to capture and represent knowledge typically from a domain-specific problem (Beydoun & Hoffmann, 2013). They produce deliverables for design and development of an IS for that particular domain (Yu, 1993). In a DM domain, these activities become more complicated as this particular domain problem is complex in relation to various constraints as already discussed. In software engineering, these activities are typically undertaken in the context of Requirement Analysis (RA) (Lopez-Lorca *et* *al.*, 2015). While this task is vital, many of them fail because there is no proper and clear understanding in the early stages of the development processes (Pressman, 2001; Yu *et al.*, 2011; Yu, 1997). This thesis aims to analyse and extract the knowledge from DISPLAN documents to facilitate knowledge sharing and reusing activities. These activities are undertaken by utilizing a representative methodology that can cope with the complex characteristics of DM. The DISPLAN knowledge document is in a semi-structured format which contains more data and information than in an unstructured one (Cooper *et al.*, 2001; Huang & Kuo, 2003). While the knowledge in that particular format is considered richer, it tends to be outlined in a business specification format (Selway *et al.*, 2015) that hinders ease of access. This research limits the input to semi-structured.

2.2.3 Agent-Oriented Analysis

The AOA is the analysis stage in a development life cycle based on Agent-Oriented Software Engineering (AOSE) methodology (Lopez-Lorca *et al.*, 2016). Initially, the AOSE defines a methodology in software development for Multi-Agent Systems. The AOA per se is a requirement phase that aims to capture the knowledge characteristics of a to-be-developed system. In the AOA, agent, a piece of designed autonomous software component that capable for a particular task, is the centre of the process (Ashamalla *et al.*, 2017). Nonetheless, in this research, the AOA is not aimed at component of or software development rather adopting the AOA to uncover the requirements in such complex domains.

A considerable amount of literature has shown the effectivity of AOA for codifying the knowledge from particular complex domains (Ashamalla *et al.*, 2017; Liang *et al.*, 2013; Lopez-Lorca *et al.*, 2016; Miller *et al.*, 2014; Shvartsman & Taveter, 2014), to name a few. In the most recent ones (Ashamalla *et al.*, 2017; Lopez-Lorca *et al.*, 2016; Miller *et al.*, 2014), they maximize the AOA potent in requirement stage by using it to acquire knowledge from the specified domains that have various activities and constraints. Other works can also be seen in utilising the AOA in the early requirement phase, for instances, to develop a health decision support framework (Liang *et al.*, 2013) and/or military training scenario model (Shvartsman & Taveter, 2014). All works laid out in this paragraph acknowledge that as the domains constitute of tangled characteristics then the AOA is recognised as a representative methodology for capturing them. This is because the features of the AOA per se in the complex knowledge representation which otherwise unable to appropriately capture will be costlier to fix in the later development phases (Lopez-Lorca *et al.*, 2016).

Taking into account a domain's complexities, Miller et al. (2011) show that analysing and extracting the knowledge utilizing the agent modelling approach contributes to the improvement of RA processes. The approach assists in correcting the inconsistency and incorrect knowledge extraction processes. Initially in software engineering, the RA is a set of activities that aims to analyse and portray the detail specification of functionality and non-functional properties of a system-to-be-developed from stakeholders (Yu *et al.*, 2011). Utilising the modelling processes, the employed models, for instance, the goal, role, organisation, and interaction models from the AOSE paradigm drive the requirement gathering process to become more effective, as stakeholders themselves are highly involved as the modellers. The use of modelling utilizing these particular AOSE models to support RA can also be observed in the work of other scholars; a case in point is in Lopez-Lorca *et al*. (2016). In this research, the modelling utilizing these AOSE models assists in correcting the incompleteness of a domain specification process by validating and verifying it through those models by a modeller intervention. This research uses these AOSE models and this will further demonstrate the capability for agent oriented modelling in knowledge representation. Particularly, the modelling activities and the adoption of those AOSE models will successfully clarify the fuzziness and incompleteness of DM representation. Through these particular models, socio-technical problems such as, proactiveness, reactiveness, negotiation, communication and cooperation framed in the DM timeline between so many and varied entities/actors are easily identified. In prior work, Miller *et al*. (2014) also demonstrate that the use of those typical AOSE models for analysing as well as modelling the socio-technical complex characteristics can be successfully extracted. This is supported in the early stage of the requirement analysis process (Argente *et al.*, 2011).

Uncovering intertwined and fuzzy characteristics are important in DM knowledge engineering type activities (Beydoun & Hoffmann, 2013; Jakus *et al.*, 2013; Markman, 2013). In this, a knowledge engineer carries out the analysis and codifications processes to ensure that the knowledge elements are completely extracted and subsequently understood by others (Beydoun & Hoffmann, 2001). As the knowledge needs to be shared and reused by other stakeholders then there is a need of a representative repository for the knowledge to be preserved for the basis of decision-making mechanisms in the typical disaster. However, in our context, the issue is not only representing the knowledge out of a domain but the most important part of the task is that the domain itself is a complex one. This means that the fuzzy and intertwined elements are interrelated each other in a way that they are aimed to achieve a common goal but difficult to be later disentangled. Understanding the DM domain should be taken into account initially prior to performing the analysis tasks. Since the domain is complex domain containing fuzzy and intertwined knowledge elements, the employed technique needs to ensure that the essential and relevant knowledge is fully gathered.

2.3 DM knowledge modelling

Employing AOSE paradigm has been shown to be the most representative technique in extracting the relevant and essential knowledge out of a complex domain. This approach paves the way to be utilized in representing the DM domain. As highlighted in the previous section, various researches have been extensively harnessing ABMs in for simulation purposes to distil the knowledge out of the DM domain. In this section, model, modelling and the features of modelling utilizing AOSE will be discussed and reviewed in further details.

2.3.1 Knowledge Engineering approach

Traditionally, Knowledge Engineering (KE) is a process of extracting the knowledge from the expert's mind and transferring the extracted knowledge into a Knowledge-Based System (KBS) (Beydoun & Hoffmann, 1998; Schreiber *et al.*, 2000; Wielinga *et al.*, 1992). As its purpose, KE is then associated with the construction of KBS (Alavi & Leidner, 2001; Studer *et al.*, 1998). Initially, it is assumed that the knowledge is in place already that ready to be transferred (Studer *et al.*, 1998). Thus, to enable the KBS construction to happen, there are two elements required (Jakus *et al.*, 2013): (1) a knowledge base and; (2) a reasoning engine. While the knowledge base contains the organized expert's knowledge, the reasoning engine is an automated reasoning mechanism that aims to emulate the problem solving of a human expert. In its construction, reasoning engine of KBS adopts intelligent system techniques that makes extensive use of knowledge (Markman, 2013). Intelligent system itself according to the Webster's definition (The Merriam Webster, 2017) "*is systems that perceive their environment and take actions which maximize its chances of success*". Cases in point of intelligent systems are based on algorithms of machine learning, genetics algorithm, natural language processing and so forth. However, KBS in the making differs than these intelligent systems in a way that it employs heuristic rather than algorithm approaches for decision making.

In the modern view, KBS is even approached by modelling activities. This is due to the fact that (Mougin *et al.*, 2015): firstly, domain problems modern days become more and more complex by which it is almost impossible nor necessary to extract all knowledge elements from expert's mind; secondly, the constructed KBS itself is not aimed as a container filled with the extracted knowledge from the experts' mind rather it aims as an operational model that can be adjusted to the specified real-world activities. Thus, harnessing modelling in capturing the knowledge benefits in (Aßmann *et al.*, 2006): (1) focusing on certain aspects and ignoring the rest; (2) coping with the complexities in the development processes; (3) compromising the different view between the expert, the knowledge engineer and the KBS per se; and (4) reusing and iteratively improving the models to be used in the typical domain problems that can significantly reduce the cost of development process.

A large and growing body of literature has proposed and investigated the adoption of modelling approach in KE (Studer *et al.*, 1998), for instance MIKE (Wielinga *et al.*, 1992), PROTÉGÉ-II (Eriksson *et al.*, 1995), DESIRE (Brazier *et al.*, 1997), KBSDLC (Weitzel & Kerscheberg, 1998), Generic Task (Chandrasekaran, 1986), KADS (Wielinga *et al.*, 1992) and commonKADS (Schreiber *et al.*, 1994). These approaches are successfully and widely adopted and employed in various applications, ranging from healthcare, agriculture, finance and engineering (Hidayat *et al.*, 2016; Massoud, 2015; Tsai *et al.*, 2014; Xavier *et al.*, 2013). They are all benefit of adopting modelling in KE given its features drawn in the previous paragraph. In particular, in representing the knowledge, modelling is utilized given that (Studer *et al.*, 1998) : (1) different types of knowledge are represented uniformly; (2) while other types of knowledge are not explicitly represented; (3) the knowledge is mostly represented too abstract in the KBS; and (4) the knowledge representation is still mixed between in the implementation and abstract levels.

Compared to other KE methodologies as laid out in the previous paragraph, commonKADS, the successor of KADS, is acknowledged as the most prominent one (Carlos & Mercedes, 2005; Ghaffar *et al.*, 2011; Hidayat *et al.*, 2016; Massoud, 2015; Tsai *et al.*, 2014). The commonKADS is developed promoting the key characteristics that lends itself of representing and compromising these KE issues as previously mentioned. It comprises of models that are classified into three layers: context, concept and artefact. The models in these layers essentially are organized and intended to answer these three questions "*why*", "*what*" and "*how*" (Schreiber *et al.*, 2000, pp. 17-18) respectively in an organizational setting. They are managed in a way that it is able to capture the knowledge required to solve a particular problem, namely: domain knowledge, inference knowledge and task knowledge (Jakus *et al.*, 2013).

In commonKADS, the analysis of the knowledge domain is tasked by the models in the context and concept layers. They are *organization model, task model and agent model* structured in context layer; and only the *communication model* in concept layer. However, these models, although their capabilities in analysis and representing the knowledge out of a particular domain, in the DM domain, they are not sufficient in portraying some of the characteristics as previously elucidated in Section 2.1, in particular the non-deterministic and time sensitivity characteristics. This is not to mention that the "*why*" (Yu & Mylopoulos, 1994) in the domain analysis activities that represents the motivation as to how an activity should be performed as well as the capability of perceiving the environment are not provided by in commonKADS. To tackle the issues, an extension of commonKADS, that is MAS-commonKADS is developed (Iglesias *et al.*, 1996). The adopting of MAS paradigm for the commonKADS is with the fact that the MAS per se is a methodology in software development that is initially developed to bridge the domain complexities, including sensitivity to time, uncertainty, ability to perceive an environment and to capture the intention of an activity to be represented accordingly. In the MAS-commonKADS, a new model, *coordination model* is added as an alternative model. This additional model is aimed for modelling interaction between agents in the context of software agents. Nonetheless, as the aim of the thesis is not aimed to develop MAS-software nor the component, the MAS-commonKADS is no longer relevant for further discussing in this research.

2.3.2 Modelling

In SE, modelling is an activity utilizing a model as a primary artefact to accomplish the knowledge representation task (Seidewitz, 2003). It is driven from the idea that "*everything is an object*" shifted to "*everything is a model*" (Bézivin, 2005, p. 172). This means that the relation between a domain and the model is conformation and instantiation. In other words, a model is a conceptual layer of a particular domain which means that a model can instantiate other similar domains and/or those domains conform to its model (Kühne, 2005). Modelling is advocated by OMG (van Amstel *et al.*, 2012). The OMG is a consortium of open and non-profit computer industries aimed to produce and maintain computer industry standard for being heterogeneous including interoperability, reusable and portable enterprise applications. By advocating this approach, it allows engineers to model the problems of a domain using Modelling Language (ML) instead of general formalism, which is typically incorrect to apply to all domain problems (Montrieux *et al.*, 2013). In the process of a design to the implementation, the way a modelling approach can be easily implemented by abstracting that particular domain is similar to the one in human cognitive process (Kusel *et al.*, 2013). In other words, this typical abstraction process harnessing this paradigm by humans is recognized as a part of human nature (Brambilla *et al.*, 2012).

The benefits of utilising the modelling to conceptualize a domain are: (a) a model is able to represent and describe the phenomenon of a domain (Bézivin *et al.*, 2014); (b) a model can be used to reflect the relevant properties of a domain and is not a copy of it (Seidewitz, 2003); and (c) a model is usable as the original one with respect to some purposes (Giraldo *et al.*, 2014). These features reflect that in the modelling process, a model has to be generated at the higher level of a domain. The relation between a model and the system under study that is represented is drawn in Figure 2.6.

Various scholars devoted efforts to define what a model is (Kühne, 2006; Leombruni & Richiardi, 2005; Seidewitz, 2003). Seidewitz (2003, p. 27) defines "*a model is a set of statements* *about system under study*", while Kühne (2006, p. 370) posits that "*a model is an abstraction of a (real or language based) system allowing predictions or inferences to be made*" and many others (Held *et al.*, 2014; Leombruni & Richiardi, 2005). These varying definitions reflect the fact that modelling has been widely utilized in many fields, ranging from economics, physics, mathematics and so forth (Bézivin, 2005; Leombruni & Richiardi, 2005; McBurney, 2012). However, all these various definitions agree that a model: (a) is used to represent a particular domain where the domain could be anything, tangible and/or intangible; (b) is created and managed by a modeller; (c) is used to provide a better understanding of a particular domain by others. As such, employing the model in representing a domain benefits the development process. It defines a formal process in each stage that hinders the inconsistencies between a model developed and the domain it represents. In addition, it prevents a misunderstanding between the engineers involved in a large scale and long term project where complexities existed (Attarzadeh & Hock, 2008).

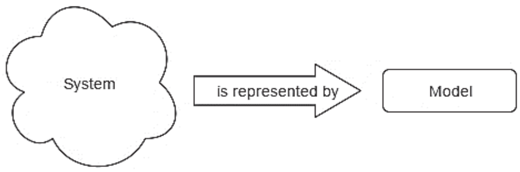


Figure 2.6 The system under study represented by modelling (adapted from (Seidewitz, 2003).

A model must be defined as accurately as possible describing the real system under study (Oliver *et al.*, 1997). However, that does not mean that the defined model should capture all details of a system or object. While a model is aimed to represent a domain, it is not intended to represent all aspects of a system (France & Rumpe, 2007). Rather, it represents only the relevant and essential characteristics as echoed by Bézivin (2005) "*a model is not intended to capture all the aspects of a system, but mainly to abstract out only some of these characteristics*". The relationship between a model and its domain being represented needs to represent the purpose of the model. A world map for example, needs to present features of the entire world but clearly not all of them. The map needs to be of an appropriate scale to be of any utility to users. The world's model in this case cannot have all details, rather it needs to only capture and extract only the relevant and essential points. In this thesis, models represent the knowledge of the DM domain. While it is envisaged as having capabilities to do that, it needs to be defined formally by conforming to its conceptual description. In the next section, this will be discussed and reviewed.

2.3.3 Model-Driven Development (MDD)

Various scholars, for instance Selic (2003), point out that although much has been done to polish the detail of the existing methodologies, like using Object-Oriented, structured paradigm, the efforts to raise the level of abstraction almost remains constant. Since software development is the domain that has gained considerable intention since almost six decades ago, the need of a technology to address these issues has emerged. In this regards Model-Driven Development (MDD) plays an important role to contribute to these issues. It is an approach in the Software Engineering (SE) field to formulate how a domain is modelled by raising the abstraction of a domain being modelled. It is defined by OMG (2013). The main objective is making a system to be simply and formally understood by others by reducing its complexities (González & Cabot, 2014). The MDD essentially is a subset of a Model-Driven Engineering (MDE), in which the focus is largely on harnessing a model in the development process (Whittle *et al.*, 2014). In MDD the pillars of the main focus are: model and the relation between model and its system understudy, metamodel and model transformations (Gaševic *et al.*, 2009). The relation between them, is similar, but not the same, to one in object-oriented relation, consisting of two main elements: instantiation and conformance (Favre, 2004). This means that the process needs to be formulized and simplified (Whittle *et al.*, 2013), by which it can be transferred and instantiated to the application level platforms (Whittenberger, 2014).

Although MDD is advocated from SE field, in this thesis the modelling paradigm employed is not aimed to develop software for a particular task. Rather, it harnesses model as a tool in the RA to model and represent the knowledge out of the DM domain. A model naturally is capable of hiding the complexities and abstracts of that particular domain while, at the same time promoting its simplicity (González & Cabot, 2014). These particular objectives by Selic (2003) are drilled down into more detail, that a model should have these capabilities: (1) *abstraction*, that is the ability of a model to hide the detail and complexities and promote the simplicity for others to be understood; (2) *understandability*, this relates to the factor that a model representing a domain should be understood easily by the interpreters; (3) *accuracy*, that a model should be in a simple form: this does not mean that it does not have to be as accurate as possible, rather a model should exhibit a domain with regards to the essential and relevant characteristics; (4) *predictability*, that a model should be able to be utilized to predict a domain in particular cases through either experiments or some formal analysis; and (5) *inexpensiveness*, that a model should be considerably cheaper to be analysed and developed than the actual system. In other words, it means that a model should not be more complex and/or bigger than the domain it represents.

2.3.4 Agent-Oriented paradigm for DM knowledge modelling

In DM domain, harnessing modelling activities for capturing the knowledge out of a complex domain has been extensively examined by various scholars (Crooks & Wise, 2013; Dawson *et al.*, 2011; Joo *et al.*, 2013; Quillinan *et al.*, 2009; Schoenharl & Madey, 2011; Shakshuki *et al.*, 2013; Wagner & Agrawal, 2014; Wang *et al.*, 2012; Wooldridge & Jennings, 1995). These scholars argue that modelling can successfully be used to uncover the complexities out of the DM domain. These can later be used in diverse system developments, for instance, in facilitating a decision support system (Nageba *et al.*, 2014), simulating and forecasting various scenarios in a particular DM (Mustapha *et al.*, 2013), transferring the knowledge to be shared and reused in the typical DM activities (Shvartsman & Taveter, 2014; Vijitpornkul & Marurngsith, 2015; Wagner & Agrawal, 2014), or developing a knowledge-based information system for the DM (Amirkhani *et al.*, 2016; Cheema *et al.*, 2016; Fikar *et al.*, 2016; Mejri & Pesaro, 2015). In our context, modelling is not employed to construct the design and implementation of a specification (prescriptive modelling). Rather, it is utilized for analysing and capturing the DM knowledge in the requirement process recognized (rather it is a form of *descriptive* modelling (Kühne, 2006)). In the context of this thesis, a model is used to comprehensively structure the DM knowledge from semi-structured DISPLAN documents. The work models the knowledge for all phases of DM (Prevention, Preparedness, Response and Recovery). In addition, models also should be able to be employed in the various best practices of DM knowledge. Eventually, the knowledge is deposited in a representative repository to allow this to be adopted by others in the typical DM activities.

As earlier discussed, ABMs from AOSE paradigm are considered as the most appropriate tool to cope with the complex nature of DM. In fact, the ABM has been widely adopted and employed in DM domain (Fiedrich & Burghardt, 2007; Hawe *et al.*, 2015; Wagner & Agrawal, 2014). ABM is employed for simulating the DM domain, for instance, in communication and interaction activities among people in a disaster situation (García-Magariño & Gutiérrez, 2013), efficiently distributing resources and allocations (Nageba *et al.*, 2014), decision making process of a sandbagging task in a response phase of a flood disaster (Padgham *et al.*, 2014), how the people in the a disaster prone-area should be moved effectively in that particular disaster type (Vijitpornkul & Marurngsith, 2015), and many more (Shakshuki *et al.*, 2013). These scholars essentially show how ABM can be applied consistently to analyse and model that complex domain and to get the knowledge out of that activity. This is due to the fact that the DM domain lends itself to be fully represented appropriately by ABMs.

The agent paradigm was conceived in the artificial intelligence communities (Wooldridge & Jennings, 1995). However, in SE communities, the adoption has been gaining considerable momentums (Wooldridge *et al.*, 1999). Indeed, it has been adopted in various fields to enhance business process contributes to the significantly pervasiveness of the complex problems, for instance, in air traffic control systems, computer systems and interfaces, transport logistics applications (Bordini *et al.*, 2007; Padgham & Winikoff, 2004; Sterling & Taveter, 2009). On the other hand, the existing methodologies are often not sufficient to cope with RA activities to model the characteristics of these typical domains.

As agent technology has attracted significant attention from the wider Software Engineering (SE) communities, appropriate tools for analysing and designing the complex problems has been pursued. They focus on how an agent is capable of dealing with capturing, explaining and predicting human's intention. However, to be able to discern what agent is, firstly, they define agent as: "*an agent is a computer system that is situated in some environment, and that is capable of autonomous action in this environment in order to meet its design objectives*" (Wooldridge & Jennings, 1995, p. 29). Following up their work, agent is then described as having the complex system characteristics, as follows:

- *Autonomy*; Agent has to have a degree of independence of action to be conducted. Agent has to react to its own goals to be pursued and to retain control over its actions and behaviours.
- *Social ability*; Agent interacts as well as communicates, and they help each other as regards pursuing their goal via a communication protocol.
- *Reactive*; Agent is situated in, and responsive to its environment. Agent will choose an alternative path to achieve a goal, if the initial approach is not working.
- *Proactive*; Agent is not only simply reacting to its environment, but also has the ability to accomplish its goal.

Taken together, agents characteristics form a distinct paradigm which differs from an object oriented paradigm, or intelligent system, or distributed computing (Jennings & Wooldridge, 1996; Padgham & Winikoff, 2004). A case in point is that being autonomous means an agent is independent and makes its own decisions. That is a key characteristic that distinguishes agent from the objects paradigm. An agent is also situated to respond to the environments that change rapidly, unpredictably and unreliably. This leads to the latter characteristic: reactiveness, as agents will adapt and change based on perceived alterations to the environment. Moreover, an agent keeps attempting to achieve its goals despite having failed in earlier attempts as the consequence of proactiveness.

There are clear similarities between agent's characteristics and the context of DM, most strikingly: agents are driven by local goals and need to interact towards a system goal; agents have specified roles and need to interact accordingly; agents are situated and need to respond in real time in many instances (Lopez-Lorca et al., 2011b). Later, there have been various attempts to use agent paradigm approach to construct the DM (Aldewereld et al., 2011; García-Magariño & Gutiérrez, 2013; Padgham et al., 2014; Scerri, et al., 2012). Nevertheless, despite of their successes, these works focus only on developing simulations of disaster events to gauge the effectiveness of existing practices. In addition, these simulations adopting ABM technology to represent the DM domain are fragmented and focused only on either a particular concept in the activities or only on a particular phase in the DM framework. For instance, while some of the simulations only focus in an evacuation activity (Mas *et al.*, 2015) or resources allocation task in the emergency situation (Hawe *et al.*, 2015) or logistic management (Gao & Xu, 2008), some are only in one particular phase, the Response phase (Joo *et al.*, 2013; Mas *et al.*, 2015; Nageba *et al.*, 2014; Scerri *et al.*, 2012a). Still, some of them only focus on simulating the activities on one or two phases in post-disaster (Response and Recovery phases) with less attention on the pre-disaster (Prevention/mitigation/planning and Preparedness phases) (Berariu *et al.*, 2016; Kimura *et al.*, 2014). Moreover, some of them only focus on the natural disasters (Fakhruddin & Chivakidakarn, 2014; Mustapha *et al.*, 2013) with little observation of the man-made/technological disaster (Jackson, 2014; Sharma *et al.*, 2015).

The simulations indeed give useful feedback based on the variables and the assumptions given to the process. In some cases, they can be precise (Funabashi & Kitazawa, 2012), for instance, in the case of the 2011 Japan tsunami disaster with the early warning system that was capable informing of the likelihood and when the tsunami would hit the land based on the magnitude of the earthquake. Another example was when the hurricane Sandy disaster struck the East Coast of the US in 2012 (Rosenzweig & Solecki, 2014). The early warning systems, based on the simulation, can predict accurately, the day, the time and how big the storm will hit the land a week before. However, the events showed that in these disasters, the impacts were more destructive and devastating than what could have been simulated (Parker, 2012; Rosenzweig & Solecki, 2014). The lessons that could be learnt from this was that equipping the stakeholders with sufficient knowledge is extremely urgent as they can adapt to the on-going circumstances accordingly (Mejri & Pesaro, 2015; Weichselgartner & Pigeon, 2015).

In this research, the knowledge is modelled utilizing AOSE approaches prior to depositing it in to a representative repository. This is with the aim to share it being reused by other stakeholders in responding the typical disasters. Ultimately it can contribute to developing the resilience endeavours (UNIDSR, 2008). It is worth noting that the adopting of the agent paradigm, as a matter of fact, constitutes an emerging trend in computer science, particular in the RA phase. However, for its development cycle (Beydoun & Hoffmann, 2013), for instance from the analysis and design, implementation and testing to the debug phases, the existing methodologies can still fit, for instance Object-Oriented development cycle (Padgham & Winikoff, 2004). In addition, in the development phase, the iterative process must be taken into account rather than the strict waterfall sequence (Winikoff & Padgham, 2013).

2.4 DM knowledge structure

In this section, the challenges prior to transferring the knowledge into a representative repository are discussed in further details. The issues discussed focus on how knowledge structures can be designed to capture DM concepts at various points in DM cycle.

2.4.1 DM knowledge representation issues

Structuring the knowledge has always been the issue in the DM domain (Briceño, 2015b; UNIDSR, 2015; UNISDR, 2005; Weichselgartner & Pigeon, 2015). Generally, the issues are related to whether the knowledge is (1) available at any point in the DM timeline to be adopted by the stakeholders and (2) understood by the stakeholders to respond to the situation in appropriate manners (Betke, 2015). While these are urgent as they are the foundation for the decision making system (Dorasamy *et al.*, 2013), the DM knowledge that is structured in the widely adopted PPRR framework (Prevention, Preparedness, Response and Recovery) is still in fuzzy and intertwined formats (Rogers, 2011). This is mostly due to the fact that the knowledge in the existing PPRR framework is arranged by delineating it in each phase based on its urgency only. In the context of DM resilience endeavours, this typical knowledge structured in the DISPLAN document does not allow it to be pinpointed and embraced by the stakeholders in a timely manner (Boin & Hart, 2010; Briceño, 2015a). For instance, the knowledge regarding the preparation for an imminent event is arranged in the Preparedness phase and the knowledge during the response is arranged in the Response phase.

In the existing and widely recognized framework of PPRR, the DM knowledge managed in those delineated phases is not followed by defining it into a holistic arrangement to which people in each level of need can understand it comprehensively. For instance, the need of knowledge for people on the decision making or on the planning or on the ground levels is different from each other. For those who are on the decision making level, the conceptual knowledge appears sufficient and in fact more effective, as they are not dealing with the technical detail type knowledge which is more suitable to those who are on the real world layer. Although the availability of the appropriate knowledge is critical, for all stakeholders regardless of which level they are on, utilizing the knowledge to comprehensively respond to the situation accordingly is clearly more important. In Figure 2.7 the complex and interrelated knowledge illustrated.

DM concepts are three dimensional (3D) structures representing the need of knowledge in each level of stakeholders, the time and PPRR framework. Prior to utilizing DM knowledge based on the need of the stakeholders, DM concepts needs to be disentangled into an understandable format. As indicated in the previous sections, the understandable format is not only about parsing the complex knowledge into the corresponding models representing its concepts, for instance, the roles, the goals, the time, the resources, the interactions, and so forth, but more importantly, whether it fits to the knowledge needs of stakeholders in each layer.

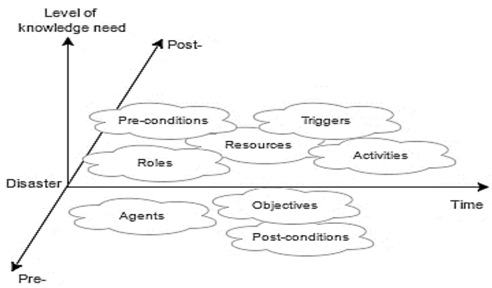


Figure 2.7 The intertwined knowledge across the DM time and the need level.

As can be seen from Figure 2.7, the knowledge needs in any intersection point of those three axes represent the actual activities with respect to each of those situations. Essentially, the stakeholders might refer to the same objective to be pursed; however, the corresponding knowledge required in one point in the timeline is different to the others. The characteristic of knowledge in the conceptual or planning level most likely is suitable for the high-level decision making mechanisms, where in the real situation it needs to be drilled down to be adapted with the people on the ground. These typical knowledge characteristics should be identified, regardless in which PPRR phases they exist.

A case in point is the evacuation warning in a flood disaster (Opper *et al.*, 2010). This is essentially a warning for all the responsible entities organized by the authoritative, one to plan evacuating people, animals and movable properties from impacted or likely impacted areas (SES Victoria Australia, 2014). The warning is issued as a result of a thorough assessment based on the information obtained from others, for instance the Bureau of Meteorology (BoM) or active reconnaissance by the authoritative agency. In that particular case, the evacuation warning as a product of the decision making mechanism can be completely understood by decision makers conceptually as it is issued at that level. However, the challenges which arise adjacent to the implementation are as how the knowledge generated in that particular level is translated to the executable format, in particular to the people on the ground, effectively and efficiently. The necessity to pin down the corresponding knowledge for those circumstances is urgent. This is because in disasters the situations are always fluctuating (Hanberger, 2015). On the other hand, with respect to the PPRR framework, while the planning of evacuation is structured in the Preparedness phase, the actual evacuation knowledge is structured in the Response phase (SES NSW Australia, 2006). While these knowledge delineations in the existing PPRR framework are important to inform the urgency of the activities, the lack of holistic structure hinders them being adopted comprehensively.

The evacuation as knowledge contains the real-world procedures and at the same time contains a planning/policy. In other words, performing the evacuation and planning for the evacuation are two different things, although they refer to the same objective. For instance, in the consequence of evacuation warning issue, prior to undertaking the evacuation activities, all the roles played by all agents in this particular circumstance need to know: which agent will play which role to evacuate properties? Which agent will handle the animal evacuation, who will handle the evacuation process of persons with disabilities? In the case of severe flooding, who will evacuate the trapped persons in the houses or on top of their roofs? What to use in the case of conducting these evacuation processes? What to use in the communication processes with the other stakeholders in conducting their tasks? In the case where it most likely that floods will occur, what are the activities to be undertaken by these agents to anticipate the inundations or flooded situations? All these knowledge elements need to be put in the first place as a rule of thumb prior to activating them.

Hence, it is apparent that in this context, recognizing the evacuation knowledge in the conceptual level is the most important thing which should also reflect the integral and holistic knowledge from the conceptual to policy or planning to the real activity layers. Subsequently, any involved stakeholder is able to harness it to take appropriate response and handle the ongoing situation. Taking the example from the previous paragraph, once a knowledge concept is identified (in this context it is the evacuation one), subsequently it can be instantiated to the lower practices: to the planning/policy and real world activity. This also applies the other way around that in case the evacuation knowledge in the lower layer is available, it conforms to the evacuation as the one in the conceptual layer. Thus, it is clear that the knowledge relationships in those levels are conformance and instantiation. In this particular example, the evacuation knowledge concept becomes the anchor or the reference to guide the formulising processes of the policy/planning. This relationship type also applies in the formulising process between policy/planning and the real-world knowledge, that is the policy/planning knowledge is the foundation to formulate real-world knowledge This knowledge relationship is illustrated in Figure 2.8.

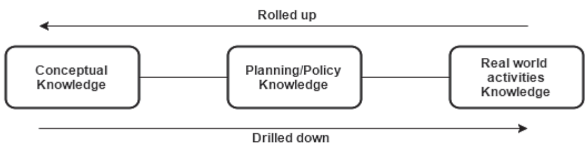


Figure 2.8 The conceptual – planning/policy – real world activity knowledge relationship.

2.4.2 Existing DM conceptualisation approaches

Various researches have been undertaken in an attempt to structure the DM knowledge to be better understood (Adrian *et al.*, 2011; Rivera *et al.*, 2015). Their approaches range from harnessing the ontology from the IS domain (Adrian *et al.*, 2014; Lauras *et al.*, 2014; Liu *et al.*, 2013; Mach *et al.*, 2000; Mescherin *et al.*, 2013a), the adoption cloud environment for managing the interoperability data (Grolinger *et al.*, 2013) to the harnessing of the Internet of Things (IoTs) to process the heterogeneous data (Poslad *et al.*, 2015).

Of all these, one of the most notable is described by Othman *et al*. (2014). In this work, they do not only prescribe how the knowledge is structured addressing the knowledge layers from conceptual to planning to the real world as discussed in the previous section. They also go beyond that by describing a proof-of-concept through developing a sophisticated architecture to allow the DM knowledge to be deposited in a metamodel-based repository (Othman & Beydoun, 2010a). The objective of their research is enabling the structured knowledge to subsequently be stored for sharing and reusing purposes by others in the typical DM activities. In the knowledge structuring processes, they employ the Meta-Object Facility (MOF) framework developed by OMG in SE domain (Othman *et al.*, 2014). Likewise, the adopting of MOF for decomposing the complexities of knowledge structure can also be observed in other studies (Chen *et al.*, 2015; Lauras *et al.*, 2015). These scholars successfully demonstrate that the knowledge is structured to be identified in the conceptual – planning/policy – real-world layers which subsequently facilitates it being transferred into the metamodel-based repository. However, the structured knowledge that resides in their repositories are still in complex knowledge structures where the fuzziness and incompleteness still exist.

For instance, as drawn in here (Othman & Beydoun, 2016), the authors describe the knowledge transfer from the DM model to the DMM they previously developed (Othman *et al.*, 2014). Nonetheless, the knowledge deposited in the DMM-based repository is still in the original format, that is managed as a business specification of the DM knowledge document. In other words, they may successfully transfer the knowledge but not converted it into a parsed structure. The roles, the responsibilities, the interactions between roles, the resources needed and so forth in the DM activities are still intertwined in paragraphs deposited to repository. However, it does not mean that the knowledge in this typical format is not useful rather in the DM activities, as time is a determinant factor, the more complete and context aware of the knowledge the better. This is because the disentangled knowledge in the repository allows the knowledge to be directly understood and executable without requiring any deductive processes.

In similar vein, the attempt of utilizing metamodel as a representative repository in the knowledge transfer can also be seen in other scholars (Benaben *et al.*, 2016; Chen *et al.*, 2015; Lauras *et al.*, 2015). However, despite their successfulness of the transfer process, the complexities keep still propagating in the repository that affect its effective use. This is not surprising as the objectives of these researches (Benaben *et al.*, 2016; Chen *et al.*, 2015; Lauras *et al.*, 2015; Othman & Beydoun, 2016) are to either construct the DM metamodel or to adopt the existing one for demonstrating the knowledge transfer process. Since the knowledge is still in the typical business-specification format then for people on the ground the typical knowledge is still largely incomplete, fuzzy, taking time to decompose particular in the emergency situation. This is not an overly strong assumption as this also has been spotted in other researches, for instance in here (Hernantes *et al.*, 2017; Mejri & Pesaro, 2015; Weichselgartner & Pigeon, 2015). They acknowledge that taking into account the domain complexities, disentangled the intertwined knowledge into the format under which it can be easily understood is considered as an effective mechanism of creating DM resilience endeavours.

It is worth noting that from DM practitioners' perspective, the knowledge structured in business specification formats does not only impede the resilience endeavours, but moreover it does not reflect the sense of DM activities naturally (Opper *et al.*, 2010). For instance, as exemplified by Opper *et al.* (2010), a particular activity in a flood disaster, evacuation, is performed based on rigorously assessment of the ongoing situation. Ideally, an evacuation decision is issued by the authoritative with a high level of confidence. This is due to the fact that the consequence is costly as it involves mobilisations and relocations for transporting people and properties in the prone area, providing shelters, etc. However, a high level of confidence decision means a low degree of uncertainty of the assessed situation. In this particular disaster, to achieve the status of confidence means the responsible authoritative might take time to assess the situation which on the other hand, it might be late already. In contrast, if the decision is made based on the high uncertainty (which means a low confidence), it turns out not a necessary evacuation. These typical issues still become the concern of the recent scholar, for instance in here (Blackman *et al.*, 2017). In Blackman *et al*., they argue that to disentangle the knowledge elements involved in the complex DM, there need a "transition" stage in between each of PPRR phases. The aim is to clarify the involved typical knowledge elements, for instance, the roles, the responsibilities, etc., for a more effective DM. Two real case studies are presented to support their arguments. Nevertheless, as acknowledged in the paper (Blackman *et al.*, 2017), conceptualising the idea is one thing, materialising it is another thing. Notwithstanding this, these examples clearly show that there are issues of the DM knowledge structure that have been acknowledged that need to be restructured and represented to enhance DM resilience endeavours.

Nonetheless, regardless of the shortcomings of the knowledge structuring processes, in the context of DM knowledge transfer process, these scholars have paved the way to the knowledge sharing and reusing by contributing to a comprehensive and sophisticated metamodel-based repository development for DM domain. In addition, the metamodel-repository in Othman and

Beydoun (2016) fits for both natural and man-made disasters and for all DM phases, while with others, their metamodel repositories are only for a particular phase and natural disaster type.

To conclude, while these researches acknowledge that structuring the knowledge is critical yet challenging, they also recognize that in DM activities knowledge sharing and reusing are considered critical given the nature of the domain is not-deterministic. In addition, they recognize that the need of DM knowledge at any point of the timeline is different where the knowledge transfer mechanism is fundamental (Abdul-Jalal *et al.*, 2013).

2.4.3 A DM knowledge representative repository

In a particular disaster type, once all the complex knowledge characteristics are analysed and structured, the next stage is it to be shared for reusing by others. This is with the fact that learning from the experiences is considered effectively and efficiently in non-deterministic circumstances (Cheema *et al.*, 2016; Drupsteen & Guldenmund, 2014; Sjøgren, 2016; Thomas, 2016; Vastveit *et al.*, 2015). Therefore, to be able to get the knowledge effectively utilized, it should cover all the relevant and essential features of the domain, for instance, the involved entities, their roles and responsibilities, their organisation constraints, their interaction and negotiation types, to what extents they need to be communicated, the triggers to activate the activities. As such, these complex elements are incorporated to be structured accordingly to allow them to be retrieved and used by others. For these reasons, the necessity to have a representative repository where the knowledge is able to, not only, be deposited to (Gallupe, 2001) but more importantly, be able to cope with those typical knowledge structures is critical (Hristidis *et al.*, 2010).

In DM activities themselves one knowledge concept is related to others (Opper *et al.*, 2010). For instance, the *evacuation* concept in a flood DM is dependent on other concepts, namely *Early Warning System* (*EWS*) and *public education*. This means that to be able to conceive a broader understanding toward effective evacuation activities, the stakeholders also need to acquire the *EWS* and *public education* knowledge in the first place. In other words, laying down all these various interrelated knowledge concepts in the beginning is advocated. In the decision-making system, these typical knowledge structures facilitate the DM activities more comprehensively. This is because the involved entities will have the necessary knowledge which they are able to follow at the appropriate time.

Drawing upon these issues, there are a number of researches which have been devoted to an attempt to develop a representative repository. Grolinger *et al*. (2015) develop a repository which harnesses a cloud computing technology to store the DM knowledge from heterogeneous inputs. The inputs are from any type of data, such as, social medias, blogs, web pages, pdfs and in any different formats. They undergo a pre-processing task harnessing ontology technique that is defined as a set of acquisition processes to extract and structure the data and information of a domain to become knowledge (Beydoun & Low, 2016), prior to transferring it into the cloud-based repository. At the end, the stakeholders query the various and large amount of knowledge that has been stored based on the structured ontology in the repository. By the same token, the use of the ontology approach to extract and structure the DM knowledge for sharing and reusing can also be observed in these researches (Adrian *et al.*, 2014; Little & Rogova, 2005; Mescherin *et al.*, 2013b). Unlike the others, although in their research, Adrian *et al.* (2014) develop an ontology only for a particular type of disaster, namely crime mapping DM, they develop a proof-of-concept as a prototype utilizing the web-based technology for the users interacting with the system. Eventually, the knowledge can be reused by retrieving it for different typical DM. The way it is retrieved is fundamentally a reasoning process between data and information of the ontology structure in the repository and the specific instance of the event. They both can be perfectly mapped, if they represent the same knowledge.

Nevertheless, harnessing the ontology for structuring the repository means that it can only be effective if it is guided to extract only the relevant knowledge concepts which it is aimed for (Bera *et al.*, 2011). In other words, by employing the ontology approaches, there will be an infinite knowledge concept that could possibly appear in which they might or might not be useful in a DM activity. This is because in ontology the concepts extracted from a domain could form an unlimited tree (Beydoun *et al.*, 2011). In the context of DM resilience endeavours, this can be the factor that impedes the knowledge being adopted as resulting concepts might be anything that are not relevant and essential for the DM activities, particularly for a decision support system mechanism.

Fundamentally, the reasoning processes on how to retrieve the knowledge from the repository is the case-based reasoning as illustrated in (Otim, 2006). This is essentially the mapping process between the existing knowledge of any event that is previously stored in the repository and one that is occurring with the similar criteria. For instance, if the case is to provide a flood warning scenario then to be able to have the corresponding knowledge elements regarding the event is by mapping it with the existing similar scenario deposited previously in repository. It means every time new knowledge is added, it is always considered as a different scenario, although it comes from similar disasters that have previously been deposited in the repository. This implies that in the mapping process both the knowledge concept in the repository and the one related to a particular activity might never be matched.

Similarly, this approach can also be observed in Heard *et al*. (2014), although they present a more interactive and real time approach in term of sharing and reusing tasks. However, in their study, given the repository format, the way the users deposit the knowledge to the database and retrieve it depends on their interpretations per se. In other words, whenever and whatever data and information are considered important subjectively by the users, they can be laid down into the repository which later allows them to be retrieved and reused. While the users are not always the ones that have DM knowledge background, the deposited knowledge could be anything with less meaning that has no relevance directly to the DM activities. For the DM decision making mechanism, this typical knowledge structure contributes to ineffective and inefficient tasks, because of various constraints to be considered, such as time, resources, dynamic variable forecasting. In addition, for the system devised for a real time processing, the network dependency and bandwidth stability are challenging. While this might work for pre-disaster (Prevention and Preparedness phases), it might not be applied in post-disaster (Response and Recovery phases), particularly in a devastated impact of disasters, for instance, in the Nepal Earthquake, Japan Earthquake and Nuclear disaster. In these particular disasters, the network infrastructures might have totally collapsed.

2.4.4 Metamodel-based repository

Another approach that has been gaining considerable attention recently for structuring a DM repository is the metamodel technology (Benaben *et al.*, 2016; Chen *et al.*, 2015; Kaptan, 2014; Kirillov *et al.*, 2012; Lauras *et al.*, 2015; Othman & Beydoun, 2010b; Ramete *et al.*, 2012; Seo *et al.*, 2012). It is developed conforming the MDD paradigm (Kulkarni, 2013). The structure of the metamodel is about concepts and their relationships (Beydoun *et al.*, 2009a). The relationships relate all the concepts with respect to their relevancies. The concepts and their relations identified in the DMM are based on the rigour evaluation, for instance using a frequency-based selection technique (Othman & Beydoun, 2012). The metamodel guarantees the knowledge concept completeness (Atkinson & Kuhne, 2003). In the development process, various models of DM domain are populated and synthesized based on their common and similarity constructs, subsequently transforming them into a generic DM one in the higher abstraction layer, called DM metamodel (the DMM, after the term coined by Othman and Beydoun (2010b)). The generic one serves as a model in which all those DM models conform to or can be used to initiate other DM models.

Unlike the ontology approach as explained in the previous section, the concepts and relations in DM metamodel structure are extracted from the most relevant and the existing ones across the multitude of DM models. Thus, while ontologies and metamodels appear to have similar paths in conceptualizing a domain (Henderson-Sellers, 2011), the way they are evaluated determines the magnitude of their impact particularly in this context. Thus, this metamodel repository structure is a considerable improvement, not only, as to how the knowledge is placed in it as it has been identified and laid out in it previously, but more importantly it redefines the way the decision-making process is generated, as it relates the most relevant and essential knowledge concepts in the DM domain. Thus, the users are able to point out not only the corresponding concept in the repository and its associated ongoing event to map with, but also the related ones linked to it. As a result of these features, the metamodel structure, by far, is considered as the most representative repository for facilitating the DM knowledge to be deposited into.

The aim of this thesis is to develop a systematic DM knowledge transfer process. The knowledge modelling is discussed in Section 2.3 and the repository is reviewed in this section. Once the knowledge is extracted and modelled, and the repository is in place, the next stage is allowing this knowledge transfer process to take place by facilitating the transfer mechanism. In the next section, this mechanism will be discussed and investigated.

2.5 DM knowledge transfer mechanisms

The DM knowledge transfer mechanisms here refer to the transferring process of the DM knowledge that has been analysed and modelled utilizing ABMs into the DMM-based repository. Therefore, as elaborated on in the previous sections, both ends, ABMs of DM knowledge and the repository where these models will be transferred to should be shaped from the outset. In this section, the ideas and issues of the transfer process will be reviewed based on the existing and relevant works.

2.5.1 Meta-Object Facility

The key element of the knowledge transfer in this research is essentially model transformations. As indicated previously, the model transformations approach is employed as it is used in two activities: (1) in analysing the knowledge from the DM domain and structuring them into each of the corresponding ABMs. The resultant of this process is the AB knowledge models; and (2) in identifying that metamodel structure, the DMM, is considered as the most representative repository in this context. According to MOF, essentially a metamodel is a model per se organized in the different layers (Sendall & Kozaczynski, 2003). Thus, in this context, transferring the knowledge into its repository is essentially a model to model transformation (Bettin, 2004; Daniel & Matera, 2014). In other words, knowledge structured in models is transferred into its repository that is also formatted in a model. This is illustrated in Figure 2.9.

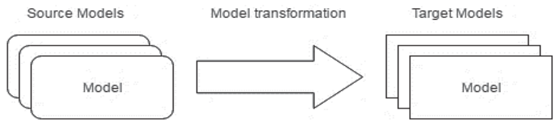


Figure 2.9 The model transformation concept (adapted from (Biehl, 2010).

The MOF frames this model transformation to comply with MOF mechanisms to ensure the correctness between before and after the transfer process (Wimmer *et al.*, 2012). The MOF consists of a four-layer structure as illustrated in Figure 2.10. The relation between layer *M0* and the layers above is the conformation. It means *M0* conforms to *M1*, *M1* conforms to *M2* and so on. On the contrary, the relation between the layer *M3* and the layers underneath it is an instantiation. The instantiate relation between layers basically has the cardinality degree as one-to-many (or otherwise a many-to-one). This means, a model in a higher layer can instantiate more than one model in the lower layer. Conversely, this relation informs that the models in the lower layer conform to the one structured in the higher layer. The lower layer refers to the real domain problem and the higher one refers to its conceptualisation. Thus, in this thesis, *M0* is the DM knowledge of the real-world activities, which is the knowledge from the best practices characterised by complexities that need to be shared and reused by other stakeholders in the typical DM activities. The *M1* is the model representing the DM knowledge from the real-world activities (*M0*). The *M2* is the metamodel of the models in the *M1*, and *M3* is the MOF per se.

Conceptually in this thesis, knowledge from the *M0* layer is analysed and structured in *M1*. Subsequently it will be transferred into the *M2*, the metamodel layer. To enable this process, a set of relationships must be defined between elements of source and target models (Sendall & Kozaczynski, 2003). It requires an understanding of the model in the abstraction level to be able to develop a clear sense for this particular task (Jiménez *et al.*, 2013). In this regard, the metamodeling MOF is a common technique to define the abstract syntax and interrelationship semantics of models (Levendovszky *et al.*, 2014). In the context of knowledge transfer mechanism, employing the MOF as the framework regulates the process as defined by OMG (2013).

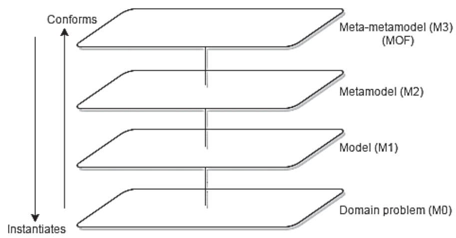


Figure 2.10 The Meta-Object Facility (MOF) layers (OMG, 2013).

The MOF is the core element of the Model-Driven Architecture (MDA) proposed by OMG to enable the development and interoperability in the approaches where model and model-driven system are the core principles (Overbeek, 2006). The model-driven paradigm is basically the foundation where "*models can be exported from one application, imported into another, transported across a network, stored in a repository and then retrieved, rendered into different formats (including XMI, OMG's XML-based standard format for model transmission and storage), transformed, and used to generate application code*" (OMG, 2016). Put simply, the MOF provides a mechanism for manipulating a model (Biehl, 2010), which is the capability to transform it up and down following the layers in the MOF framework (Mens & Van Gorp, 2006; Wimmer *et al.*, 2007).

As indicated previously, the challenges in the first place emanate from the complex characteristics across the DM knowledge in the DISPLAN that need to be analysed and modelled. The analysis framework essentially aims at extracting all those complexities and at the same time preparing them for a depositing process into the repository. A representative repository which can cope with all those complexities should also be prepared to allow the transferring process. Once the model and repository are in place, the transfer process is enacted. The illustration of this is shown in Figure 2.11.

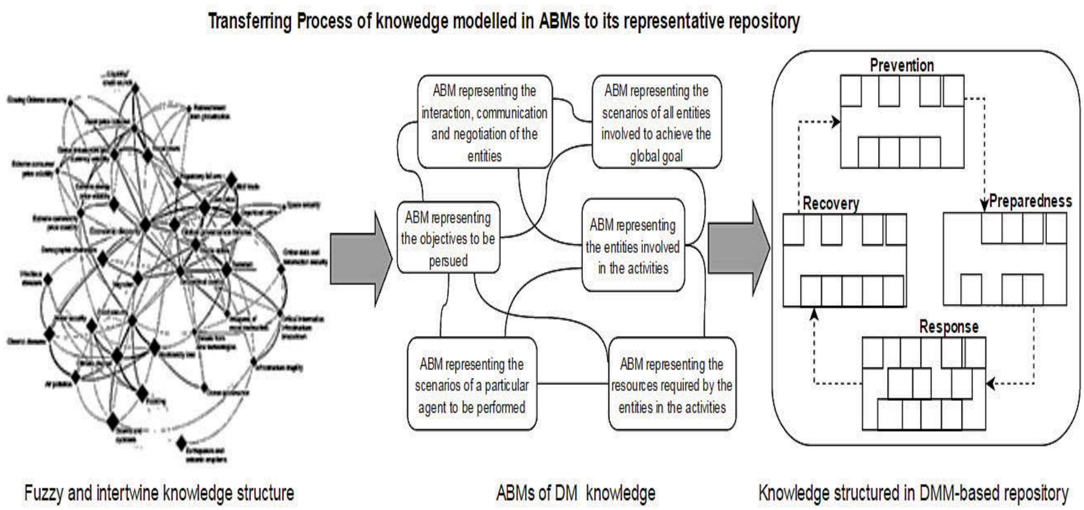


Figure 2.11. A conceptual model of knowledge transfer mechanism based on MOF.

Recently, a considerable body of literature has grown up around the theme of harnessing this typical knowledge transfer process, particularly in the last few years (Benaben *et al.*, 2016; Chen *et al.*, 2014; Kaptan, 2014; Kirillov *et al.*, 2012; Lauras *et al.*, 2015; Othman *et al.*, 2014; Ramete *et al.*, 2012; Seo *et al.*, 2012). Probably the most notably one is illustrated in Othman's and Beydoun's study (2016). Unlike others, Othman and Beydoun (2016) not only conceptualize the knowledge transfer mechanism but more importantly they also exhibit its implementation by developing a prototype of the sophisticated architecture of the metamodel-based repository (Othman & Beydoun, 2010b), namely Disaster Management Knowledge Repository (DMKR).

Moreover, the repository covers all four phases of DM framework: Prevention/Mitigation (P), Preparedness (P), Response (R) and Recovery (R) and can be applied for both natural and man-made/technological disasters.

By contrast, some other studies successfully show how the knowledge is transferred into the metamodel-based repository; however, their employed metamodels are only for either one particular phase or DM type and are not aimed to cover both disaster categories. For instance, Chen *et al*. (2014) and Ramete *et al*. (2012) specify the metamodel only for flood and road crisis DM, respectively. On the other hand, Lauras *et al*. (2015) and Benaben *et al*. (2016), developed metamodels only for Preparedness and Response phase. Moreover, as the objective of the metamodel is completeness, the development of their metamodels becomes an issue, since there is no clear information whether their metamodels are constructed and cover the relevant and essential model elements or whether they can be used as representations of models underneath. Despite some discrepancies, in many ways, all these scholars successfully exhibit that their knowledge transfer frameworks work as intended. They harness the DM models from the existing works to analyse and model the knowledge from the real-world activities prior to transferring it into the metamodel-based repository, following the MOF framework.

In the context of this research the depositing process cannot be performed automatically. This is due to the fact that the paradigm differences of those two model-driven approaches hinder them being mapped directly. The harnessing of ABM from AOSE paradigm that is considered as the most representative methodology to decompose those complex knowledge characteristics prior to the transfer process raises some consequences. These relate to the components in the developed framework. They are described in sections that follow.

2.5.2 Preparing a representative repository

In regards to the MOF framework, the knowledge in the *M0* layer will be analysed and modelled with respect to the AOSE paradigm and structured in each of the corresponding ABMs in the *M1* layer. These models are subsequently transferred into the metamodel repository layer, the *M2* layer. This implies that the metamodel-based repository needs to adjust its structure for that particular purpose. This cannot be the other way around, as in this thesis the knowledge transfer mechanism boils down to the need to address the issues of knowledge complex characteristics of the DM domain. Therefore, that is the repository structure, the DMM-based, that needs to be converted to the AOSE paradigm, the AB metamodel, following the paradigm in the modelling level. In other words, since the adopted models are in the AOSE paradigm then the metamodel is also formed into the same one. Once the metamodel-based repository is in the same AOSE paradigm as the models, the transformation can be proceed. This means transferring the knowledge modelled and structured into the corresponding ABMs into the metamodel-based repository. In this context, it essentially is what is referred to as the model to model transformation.

With respect to the MDD paradigm, transforming a model (or metamodel) into other models (or others metamodels) essentially is a process to extend the model by annotating extra information to that particular model (Syriani *et al.*, 2013). In model-driven paradigm, it is governed by OMG-MOF (OMG, 2013). Fundamentally, the OMG defines this annotation process by tagging a particular model with information that can represent it by only observing particular information in it externally (Sánchez-Cuadrado *et al.*, 2012). The aim is to facilitate model integration and reuse (Kusel *et al.*, 2013) and shield its complexities (Kolovos *et al.*, 2010) without modifying its originality (Fill, 2014). In the MOF framework "*a tag represents a single piece of information that can be associated with any number of model elements*". This also means that "*a model element can be associated with many tags*" and therefore "*the same tag can be associated with many model elements*" (OMG, 2013 page 27). In this research, to facilitate the knowledge transform process, the converting of the metamodel to the AOSE metamodel form should be performed first. This process follows the above explanation regarding the transformation process. This is conducted by tagging the original DM metamodel concept with its associated one of the existing and appropriate AOSE metamodel. As such, to allow this to happen, a representative AOSE metamodel that can be used for this task is sought as the challenge.

In the SE domain, there have been various attempts to develop an AOSE metamodel (Beydoun *et al.*, 2005), for instance TAO (Silva *et al.*, 2004) and Islander (Esteva *et al.*, 2002). They are developed for different particular purposes, such as, aspect oriented programming, software architecture and multi-agent system (Beydoun *et al.*, 2009a). These variants are due to the fact that domain complexities become massive these days and AOSE approach is acknowledged as having the capability to cope and portray diverse complex domains. AOSE methodology guides the analysis and design of ABM development (Padgham & Winikoff, 2004). The consequence is that there are various ABMs developed as part of the developed methodologies. Some of them are developed for a particular domain problem and others for some others (Beydoun *et al.*, 2013a), for instance some of them discuss the social ability of the agent, some examine the pro-activeness and investigate the reactiveness.

As for the users who are in the positon not to develop one but utilizing them for designing other things, this can be a hurdle as there are many models proposed for the same particular issues. Determining the one that is envisaged as the most appropriate for each problem requires a very considerable effort. To tackle this, there have been many attempts to abstract all the models by creating a unified model, the metamodel. This is the motivation of the metamodel development. The benefit of using the metamodel is that the effort of developing a particular ABM will be switched to the model development processes instead of searching into the dispersed collection of the existing ones (Beydoun *et al.*, 2005). As such, it will lead to a better communication among scholars in this field as they can all refer to same concept, the metamodel (Beydoun *et al.*, 2006).

However, as there are a multitude of AOSE metamodels, determining an AOSE metamodel that is considered as the most representative is extremely challenging. The issue is that each of them might have different concepts and relations, even though, they might refer to the same thing. Therefore, this leads to the consequence of whether it is required to develop a unified one from scratch reconciling all the disparities or employing an existing one that is conceived as the most representative having considered all the existing ones. Both these options have serious further consequences that are discussed in the following section.

2.5.3 The interoperability of the knowledge concepts

In the transferring process mechanism, the interoperability issues will be the challenges as the knowledge concepts in the metamodel layer (*M2*) and the knowledge in its lower layers (*M0-M1*) might have differences in knowledge structures while they fundamentally refer to the same semantic meaning. To be able to achieve the transfer process successfully in this particular case, the process should provide a mechanism for mapping knowledge concept accordingly. Each of the knowledge concepts in the metamodel and its lower layer should be mapped based on their semantic representations, as they basically refer to the same thing although their written forms tend to be different (Madnick & Zhu, 2006).

The knowledge transfer processes that employ a semantic mapping process have been extensively discussed (Reeve & Han, 2005). The model, that is rooted in a sound and rigorous methodology of MDD, is used by software engineers to represent a domain in the higher abstraction layer (Atkinson & Kuhne, 2003). While models constitute a coordinated and networked system, their interconnectedness requires them to interchange their data. However, as they are originally developed for different purposes and from different sources and by different developers, models cannot be automatically drawn from one to another. In fact, reciprocal model exchanges are extremely challenging as models fundamentally represent the view of the researchers (Beydoun *et al.*, 2009a). This research shows how a generic AOSE metamodel is developed. In the process, all the prominent AOSE metamodels are populated, subsequently reconciling their disparity concepts in order to generate a comprehensive and generic metamodel. This is an extremely challenging task. The issue is that they are from different sources with different metadata that need to be synchronized. For instance, these two phrases: "*June 20, 2000*" and "*the last day of the first spring in the second millennium*" (Harel & Rumpe, 2004, page 64) show they are essentially referring to the same thing semantically; however, structurally their knowledge elements are different. While both phrases have the same meaning, their syntaxes are different as they might be developed for different tasks and contexts.

With regards to these, the MOF is advocated to address the barriers by specifying the metadata management framework which enables model interoperability and metadata transformations (OMG, 2013). In this thesis, the natural language is the element of ABM used for the modelling of the DM domain. This is as shown as the example in the previous paragraph. The harnessing of natural language in the modelling informs that the interoperability issues of the knowledge models in the transform process can be approached by mapping their semantic meanings. In other words, the transformation process between knowledge concepts of ABMs to the repository fundamentally can be achieved by reconciling their semantic meanings.

In SE itself, semantic annotation approaches have been extensively discussed (Gagnon *et al.*, 2013; Kusel *et al.*, 2013; Wang & Hsiao, 2014) and the various accompanying tools are also developed for that particular purpose (Dingli *et al.*, 2003; Kogut & Holmes, 2001; Popov *et al.*, 2003). While some approaches are processed manually, for instance as discussed in (Oren *et al.*, 2006), some are semi-automatic (Handschuh *et al.*, 2002; Vargas-Vera *et al.*, 2002). The annotation process itself will be iterative; therefore a manual approach may lead to a bottleneck (Maedche & Staab, 2001). A human intervention to some extent is still required in all extant semantic annotation systems where they are not possible yet to be undertaken fully automatically (Siorpaes & Simperl, 2010). In fact, in this context, there is no system that can replace a human's capability as the best annotator (Reeve & Han, 2005). It is worth noting that the semantic annotation has also been widely recognized in the IS field (Ramaprasad et al., 2016). It is referred to as an ontology (Beydoun *et al.*, 2014; Liao *et al.*, 2011; Omoronyia *et al.*, 2010) as echoed by Talantikite *et al*. (2009, p. 1109) "*a semantic annotation is referent to an ontology*". Ontology itself is defined as an "*explicit specification of a conceptualization*" (Gruber, 1993, p. 199). In the SE domain, the foundational ontology is also referred to as a metamodel (Henderson-Sellers, 2011). However, ontology discourse is out of the scope of this research. In the context of this research, as discussed previously that metamodel structure with all its prominence is justified as the most representative as a repository in this context.

2.6 Conclusion

The literature review presented in this chapter highlights an important gap in knowledge representation taking into account the characteristics of DM domain. In particular, metamodel is acknowledged as a representative format to be used for depositing the complex characteristics out of that particular domain. Metamodel underpins the repository foundation where represented knowledge is stored to. As previously elaborated that given the key objective of metamodel is a completeness, a set of relevant and essential concepts and their relations needs to be identified and synthesized to develop a complete metamodel encompassing the concepts of the entire identified models. As previously highlighted, in the KE field, conceptualising the phenomenon of a domain is also the objective of ontology. Nevertheless, in ontology, the conceptualisation can only be carried out descriptively, which in KE it refers to descriptive modelling. This is because in ontology the truth lies in reality. In contrast, a metamodel might describe different kinds of reality e.g. domain, language or system. Thus, metamodel could be descriptive or prescriptive modelling.

As depicted in previously, ontology also has ability to abstract the concepts and constraints used explicitly. This means that anything that has not been defined, in ontology, is unknown whereas in metamodel, it is implicitly allowed or disallowed. This is because the mission of ontology is consistency. In other words, there need an agreement of the shared/standardized concepts among group of people for that particular domain. In contrast, concepts in metamodel are not required to be shared as for confining an arbitrary extension of the system that may lead to inconsistencies.

In the context of this research, as the focus of the domain problem is DM which is characterised by non-deterministic circumstance, the unknown or has not been specified yet situation is inherent. As the situation evolves, this will lead to a new insight how to handle it. As learning from the best experience is considered the best lesson learnt, there might always a new concept arisen from those experiences as there is no identical disaster. Therefore, although both metamodel and ontology have been utilised widely for portraying the phenomenon of reality, in our context, metamodel is acknowledged to be the most representative format for a knowledge repository given this research context. This is not to mention that as knowledge representation technique being employed in this research is Agent-Based Model (ABM) given its features. As employing modelling, the interoperability issues between knowledge modelled and its metamodel has been maturely prescribed and discussed, that is the MOF. Employing MOF guarantees that the knowledge being conceptualised in the modelling layer can be rolled up to its abstraction layer or drilled down to its executable layer easily. This means that the knowledge conversion within these layers is relatively easier to be synchronised and managed.

In representing the knowledge out of a domain, essentially, the literature review of KE also laid out other methodologies taking into account modelling as the mechanism for that purpose.

These methodologies propose various models that are also capable in representing the know-how of organisational activities as in the AB paradigm. However, given the unique characteristics of the DM domain that aims to capture, ABM of AOSE is considered richer in that the type and number of models and their knowledge element structures that fully capable to represent the intertwined and complex characteristics in the domain. In particular, ABM has ability to cope with the element time that trigger the DM activities and dynamic environment evolving overtime as the nature of disasters.

In the context of knowledge transfer, according to MOF, rolling up the model to its upper layer means that it is converted to its representative concepts and their relations into its higher abstraction concept, the metamodel. On the other hand, drilling down the model to its lower layer constitutes the transferring process of it to the real-world layer. In the rolling up process, the literature review showed that given the knowledge representation utilises ABMs, an AOSE metamodel is required. This aims to guarantee the interoperability between the ABM and its metamodel. In other words, the transferring process of the models to its metamodel can only be proceed only if they are in the same paradigm. Thus, AOSE metamodel is needed to allow transfer process to happen. The literature review has also shown that as the focus of the research is to develop a framework enabling the knowledge transfer, thus instead of developed a new AOSE metamodel for this purpose, the most complete and representative one among the existing ones will be adopted and utilised. In fact, there are many developed AOSE metamodel for different purposes. Thus, a scrutiny identification is then required to select the one fit best for this thesis proposal.

As metamodels, in fact, might be developed for different purposes, contexts and by different developers, the annotation process guarantees the flexibility in the mapping process of these different knowledge models and the metamodel based on their semantic similarities. In our context, given metamodel is a model per se, the annotation process guarantees that the mapping process can be taken place between metamodel and metamodel or model to metamodel.

2.7 Chapter Summary

This chapter reviewed the background and existing related works underpinning the research. The review is begun from the identification all the related characteristics encompassing and forming the DM as a complex domain. All the relevant and existing DM literatures are engaged in constructing these characteristics. Systematically identifying these characteristics is crucial as they are not only underlying the motivation to fill the gaps for which the authors aim to contribute to but more important they underpin the whole discussions of this study.

Through the literature reviews, the particular modelling employing ABM is reviewed as the most representative tool to analyse and extract all the knowledge characteristics identified in the first place. The ABM itself has so much in common in terms of the characteristics compared to ones in DM domain. In fact, the AOSE paradigm that produced ABM templates is developed driven by the fact that complexities these days exist in almost all domains including the DM. Given all its prominence, the DM lends itself to be represented by that particular paradigm. The complex characteristics can be represented by the ABMs and can accommodate the representation of DM. I.e. the DM domain lends itself to be represented by modelling task through ABM.

The ultimate goal of the research is to share the DM knowledge to be reused by others in the typical DM activities. Therefore, once all the DM elements are analysed and modelled, the next to put in place is a representative repository where the knowledge can be deposited to. As a consequence of the indicated goal, there are two components that need to be prepared, namely, preparing the repository and prescribing the transfer mechanism itself. Most literature reviews proposed the metamodel structure as the most representative repository. This is due to the fact that (1) metamodel is about concepts and relations. In our context, all the relevant and essential DM domain concepts are identified and related to each other in a way that they form a DM metamodel, the DMM. This implies that the DM stakeholders can embrace the knowledge concepts identified in the DMM to generate the relevant and necessary ones to be applicable in the real-world activities; (2) metamodel structure allows the DM knowledge to be identified efficiently. In other words, by harnessing the metamodel structure, all the relevant and essential knowledge concepts have been identified and are ready to be used. The literature review shows that to allow the transferring process, the DMM is prepared using an AOSE metamodel as a bridge between ABM elements and DMM elements.

Once the repository is in place, subsequently the literature review elaborates issues pertaining to the transfer mechanisms. A MOF framework frames the process and a semantic mapping process is involved to ensure the knowledge in the ABM structure is being transferred into the repository. It is also identified that the process involves a human as the best interpreter. This thesis contributes in this process of framework development to allow the knowledge to be analysed and transferred into the repository.

3 Research Design

In Chapter 2, leveraging the ABM and DMM as the basis of a representative repository as well as their transfer process were reviewed and discussed. The ABMs in AOSE are used to analyse and model the complex knowledge of the DM domain. However, as discussed in the literature review, although the models and the repository are in place, the knowledge transfer cannot be processed directly. This chapter elaborates on the research design by providing details of the transferring process between both ends systematically to conducting its evaluation processes framed in a Design Science Research (DSR) methodology, rigorously. In Section 3.1, the research objectives are formulised in five phases. In Section 3.2 to 3.5, each of the phases is discussed in detail and followed by the conclusion in Section 3.6.

3.1 Design Science Research in IS

In IS research, two paradigms dominate: the behavioural science and the DSR (Hevner *et al.*, 2004). The behavioural science attempts to explain and predict, based on the observational activities, the impact of IS adoption to individuals, groups or organisations. In contrast, the DSR, which has its roots in engineering and science, seeks to create innovation through analysis, design and implementation towards more effective and efficient use of the IS (Hevner & Chatterjee, 2010). Therefore, the focus in the DSR is to investigate a new artefact (Gregor & Hevner, 2013). Nevertheless, both paradigms are inseparable in IS research, as the two sides of the same coin. Both seek to extend the boundaries of human and organisation capabilities.

The DSR research, which is the driver in this thesis, aims to create new and innovative solutions including socio-technical artefacts such as decision support systems, governance strategies, methods for IS evaluation and IS change interventions (Miah *et al.*, 2017; Miah *et al.*, 2016; Shrestha *et al.*, 2014). Hevner et al. (2004) have laid a foundation of a concise framework upon how the DSR is undertaken in the IS, in terms of contributing and producing rigorous IS artefacts (Chatterjee, 2015). They developed a three-stage cycle (as drawn in Figure 3.1) as a framework to be able to contribute in the DSR by producing innovative new artefacts. These artefacts, as the product resulting from the DSR activities, include the following (March & Smith, 1995):

- **Constructs**: These provide the vocabulary and symbols used to define and understand problems and solutions. The correct constructs have a significant impact on the way in which tasks and problems are conceived, and they enable the construction of models for the problem and solution domains. For example, 'entities' and 'relationships' are constructs in the field of information modelling.
- **Models**: These are designed representations of the problem and possible solutions. For example, mathematical models, diagrammatical models, and logic models are widely used in the IS field, and new and more useful models are continually being developed.
- **Methods**: These provide the instructions for performing goal-driven activities. Examples are algorithms, practices, and recipes for performing a task.
- **Instantiations**: These are physical realisations that act on the natural world such as an IS that stores, retrieves, and analyses customer relationship data. Instantiations can embody design knowledge, possibly in the absence of more explicit descriptions. Examples are IS that store, retrieve, and analyse customer relationship data.

The aim of the DSR of IS presented in this thesis is to develop a knowledge analysis framework that can be used by DM domain stakeholders to analyse and model the knowledge which is laid down in a semi-structured format. In the process, it needs to ensure that the fuzziness and interwoven complex knowledge is disentangled, subsequently deposited into a representative repository facilitating the sharing and reusing processes. Ultimately, this aims to contribute in the DM resilience endeavours by enabling others to learn efficiently and effectively from the past. Moreover, the developed artefacts composing this framework in this thesis need to be evaluated internally to ensure that the validity threats are mitigated. This is followed by evaluating the framework externally through case studies to assure the efficacy and effectiveness of the developed framework.

With respect to the DSR, the artefacts are developed based on the actual environment observation of potential opportunities to improve the practice (Iivari, 2007). With respect to Hevner's DSR, that particular observation is the first stage of a three-cycle development and is referred to as a "*relevance cycle*" (Hevner, 2007, p. 2) (see Figure 3.1). The observation can result from the interactions among people, organisation and technical systems in achieving a particular goal (Iivari, 2015). In the context of this thesis, the observation is conducted in the DM domain, particularly in the knowledge analysis mechanism to facilitate the knowledge sharing and reusing. The gap and all its related elements are identified. This then becomes the foundation of the next DSR cycle that is designing and building the artefacts and processes. This is regarded as the heart of the DSR (Hevner & Chatterjee, 2010).

As indicated previously, following the DSR research process, once the problems are observed and identified, they are followed by developing the initial artefact to address them. Subsequently, once it is built, an evaluation process of the developed artefacts is required initially to justify their utilities in solving identified problems. Both building and evaluation processes fundamentally are the second stage of Hevner's DSR three-cycle and referred to as a "*design cycle*" (see Figure 3.1). Particularly in the evaluation stage, Hevner *et al*. (2004, p. 80 Figure 2) propose that it could be either: "*analytical, case study, experimental, field study or simulation"*. In his subsequent work, Hevner (2007) points out that evaluating a DSR artefact must be well conducted to ensure its validity; as stated "*artefacts must be rigorously and thoroughly tested in laboratory and experimental situations before releasing the artefact into field testing along the relevance cycle*" (Hevner, 2007, p. 5). This evaluation is a crucial and an essential activity, as it guarantees that the new proposed and developed artefacts in the DSR are achieved and works as intended (Gonzalez & Sol, 2012; Peffers *et al.*, 2012).

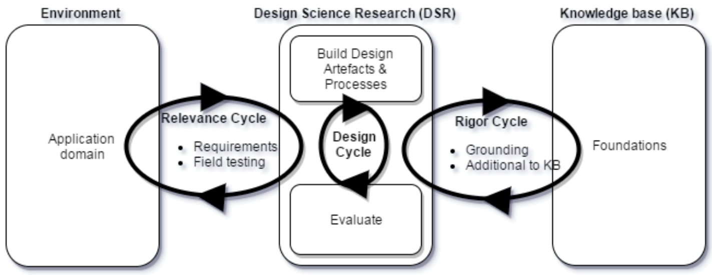


Figure 3.1 DSR cycle, adapted from (Hevner, 2007, p. 2).

In DSR, there have been various evaluation techniques proposed (Gonzalez & Sol, 2012; Peffers *et al.*, 2012; Pries-Heje *et al.*, 2008; Venable *et al.*, 2012). Peffers *et al.* (2012) begin to describe the evaluation process by defining that it can be conducted "ex ante" (before) or "ex post" (after) the artefact construction. However, as previously described, there are different artefact types (model, method, construct and instantiation). Therefore, relying only on these two types of classification is too general. This means it is urgent to have a more detailed evaluation process encompassing the developed artefacts. The issues that need to be clarified are where to start the evaluation and to what extent the evaluation of the artefacts should be. This is to ensure that they are thoroughly evaluated. To elucidate this, Gonzalez and Sol (2012) break down the existing evaluation type by defining a new set of evaluation criteria to cover the detailed aspects of artefacts. For instance, while some criteria such as completeness and simplicity, are defined for the construct artefact, the others including the criteria robustness and level of detail are for the model artefact. In this regards, although this approach informs how to perform the evaluation in more details, these proposed criteria could be infinite as it depends on the researchers' subjectivities in addressing each of their problems. In other words, the researchers can insert any criteria whenever necessary.

To address this issue, Prat *et al*. (2014) in their seminal work abstract these criteria into some dimensions. These dimensions represent and conceptualize all those criteria in the meta-analysis level. For instance, while a tool dimension represents the technology used or prototype built in developed artefact criteria, a user dimension represents the modellers, developers and programmer. The aim is to mitigate the threat of validation of developed artefacts (Venable *et al.*, 2016; Yu & Ohlund, 2012). In other words, there is a need to ensure that the developed artefacts work as intended. Therefore, the whole dimensions of the developed artefacts are required to be evaluated in order to guarantee their proof-of-concept, proof-of-acceptance and proof-of-value-added (Gregor & Hevner, 2013). In addition to performing the evaluation, both internal and external validation (Iivari, 2007), echoed by Hevner and Chatterjee (2010, p. 19) as "*multiple iterations*", need to be done to guarantee that efficacy and effectiveness of the DSR processes are achieved and work as intended. In our context, the evaluation processes involve the case studies and the experts from different authoritative DM agencies, tools developed to help the process themselves, the evaluators, the knowledge engineers. Their evaluation processes will be elaborated on in detail in the later sections in this chapter.

The third stage of the Hevner's three-cycle DSR is the "*rigor cycle*" (Hevner, 2007, p. 3) (see Figure 3.1). This is the justification whether the research contributes to a new Knowledge Base (KB) (Gregor, 2006) or is only a routine design (Gregor & Hevner, 2013). This knowledge contribution, by far, comprises "only" the consequence of the "*design cycle*" (Hevner, 2007, p. 4) in the previous stage, which therefore should be performed systematically. In this stage, the research outcome, that is the artefact per se, should be able to be communicated for the theoretical contribution of the research (Shrestha *et al.*, 2014) or the research helps to address the current problem for the practitioners (Miah *et al.*, 2014; Sein *et al.*, 2011).

Following the above elaborated DSR methodology, this research is constructed in four phases (shown in Figure 3.2). **Phase 1** focuses on defining the research problem. **Phase 2** is the development of the knowledge analysis framework. This framework is developed based on the identified problem in the previous phase. The output of this phase is the initial version of the framework. In **Phase 3,** the framework developed in Phase 2 is validated internally. This is to ensure that all aspects in the framework development are mitigated and work as intended. To allow the evaluation processes in this phase to be performed effectively, an instantiation of the developed artefact in the conceptual research is constructed. It is essentially a prototype for the evaluation purpose. The aim is to show this framework can be implemented into the technical detailed level, where it is easier to be understood by non-expert people. In **Phase 4**, the external evaluation is conducted by validating each of the artefacts composing the framework for some particular aspects. Those aspects are: formal, domain, developer, tool, user and methodology which essentially encompass the internal and external validations and represent the system dimensions, namely: goal, environment, structure, activity and evaluation (Prat *et al.*, 2014). These evaluations contribute to the improvement of the developed artefacts.

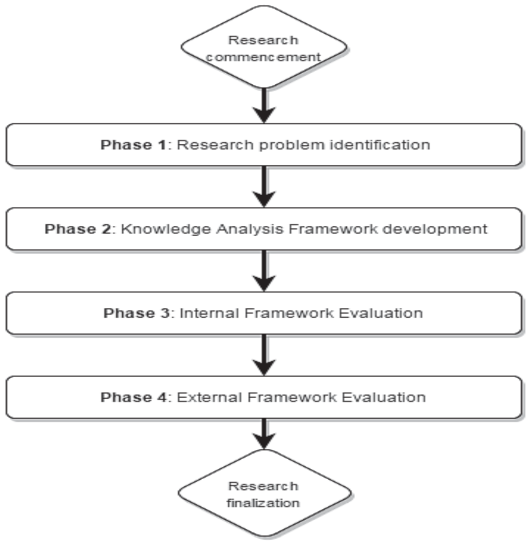


Figure 3.2 Research phases to be evaluated in this study.

A post-evaluation will also be conducted subsequent to both of these valuations. This will be conducted by a DM expert where the case study comes from. The typical evaluation aims to demonstrate the value of the knowledge to the target user groups: the DM stakeholders with evidence in addressing the benefit and usefulness criteria (Gregor & Hevner, 2013).

3.2 Phase 1: Problem Identification

The DSR methodology boils down to identifying and defining the research problem. This is a critical phase of the research cycle, as it provides a foundation which sets the direction of the research. As Gregor and Hevner (2013) have well described it, in this first phase, the research should define: a) Problem research; b) Motivation and objective of the research; c) Theoretical and practical contribution; d) Scope of the research, e) Overview of the method and findings; and f) Structure of remainder of the research. All these criteria are explained and structured to provide research justification not only in the context of the actual research that needs to be conducted, but also in the context of the knowledge contributions of the research.

For the purpose of this research, these above criteria have been discussed in Chapters 1 and 2. Problems addressed in this research have been defined in examining the DM trends and in the

DM practices vis-à-vis using decision support systems for the purpose of DM knowledge sharing and reusing. This review identified a serious gap in the conversion and representation of extant DM knowledge. This requires a fit and appropriate method for that purpose. Generally, the challenges that are discussed in the previous chapter consist of three activities. They compose the Phase 1 of the research stages as highlighted in Figure 3.3. These activities are: (1) the literature review to identify the most representative methodology to conceptualize the knowledge out of the DM domain as Activity 1; (2) the literature review to identify the most representative repository to facilitate sharing and reusing as Activity 2; and (3), the review to identify the most feasible approach as to how the knowledge identified in (1) can be deposited in (2) as Activity 3. Activity 3 is subsequently conducted once the first two have been well defined. This is with the fact the Activity 3 can only be possible to be defined systematically once both previous activities have been identified. In other words, Activity 3 can only be possible if the depositing processes between the knowledge represented in Activity 1 to the representative repository identified in Activity 2 are feasible. All the challenges and gaps are presented and examined based on the existing literatures.

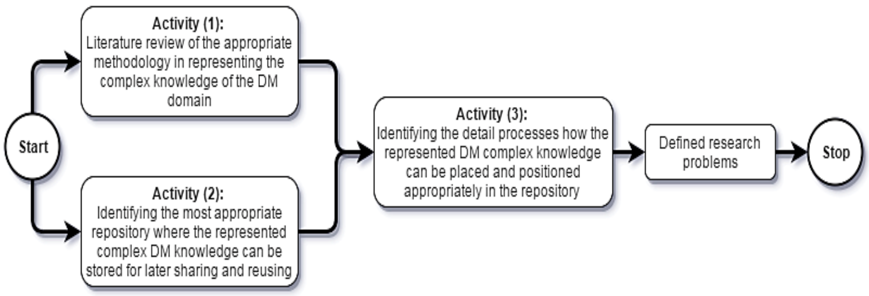


Figure 3.3 Activities in Phase 1 of the design research.

As described in Chapter 2, ABM has been recognized and used in analysis and modelling various complex domains (Lopez-Lorca *et al.*, 2011; Miller *et al.*, 2014). This thesis contributes in justifying that ABM is an effective methodology to represent the complex knowledge in the DM domain. ABMs have capability to extract the complex knowledge out of the DM domain and structure it in a way so that it can be understood comprehensively and holistically by stakeholders. Each of these models can represent the details and feature characteristics of the DM knowledge in a semi-structured format. Once analysed, they then become AB knowledge models. These can later be transformed or transferred to the later development phases for other purposes, for instance, knowledge-based information system, decision support system. In the DM endeavours, MOF framework tailoring with the AB models is identified to disentangle the complex knowledge that is fuzzy and tangled in a strict delineation PPRR (Prevention, Preparedness, Response and Recovery) framework. The process will be conducted by providing a step-by-step semi-automatic guideline for structuring the knowledge in layers, which systematically represents the knowledge at any point of the timeline in the DM activities. This is with the intention that the analysed and structured DM knowledge becomes the actual representation of the complex domain, particularly in the real DM activities.

Furthermore, as part of Phase 1, in Activity 2, identifying the compatible repository where to deposit the AB knowledge models is the next activity to be reviewed. The review identifies that DMM is an effective basis for a repository where the analysed ABMs will be deposited (Othman *et al.*, 2014). In DM activities, this particular repository is extremely urgent as the stakeholders are able to pinpoint the knowledge at any point in the disaster timeline, particularly for people on the ground.

Once the Activity 1 and 2 have been defined, in Activity 3, a review is taken to synchronize them. In other words, the AB knowledge models resulting from in Activity 1 need to be investigated under scrutiny to be deposited in the identified DMM-based repository, in Activity 2. This thesis exhibits the mapping processes between them in details, facilitating the sharing and reusing in the DM resilience endeavours. To allow this to happen, the ABMs and the DMM-based repository adopted in this thesis are used to model and to represent the DM domain. As both ABMs and DMM-based repository are developed rigorously based on the MDD, essentially they constitute models representing the system under study. ABMs represent the DM domain and the DMM-based repository represents the DM model; as such, the transferring process is conceived by mapping their semantics. All these processes are the essence of our developed framework. The evaluation subsequently validates the developed artefacts internally followed by testing with the real case studies externally. The validations are applied to the same aspects of the framework iteratively, encompassing the functionality to domain dimensions.

3.3 Phase 2: Knowledge analysis framework development

With respect to the DSR paradigm, this phase discusses the development of the knowledge analysis framework as the artefacts identified in Phase 1. This is essentially the "*design cycle*" of the Hevner's DSR three-cycle. The developed framework in this thesis is illustrated in Figure 3.4.

As depicted in the figure, the input of the framework is the DISPLAN knowledge document. It is structured in the semi-structured format. This knowledge in the document contains all the organisational know-how across all PPRR phases to be followed in the DM activities. Initially, the knowledge in each of the PPRR phases will be analysed and subsequently structured in each of the corresponding ABMs. The MOF that is tightly coupled with the ABMs serves as a framework to structure the knowledge in the ABMs into its layers. This is aimed to disentangle the complexities of the knowledge elements. The AOA is the activities referring to these processes to analyse and extract the knowledge from the knowledge DISPLAN and subsequently structure it into the ABMs. The output of this process is the AB knowledge models. These AB knowledge models that contain the analysed and structured DM knowledge will be the input for the next process. Once they are in place, they are transferred into the DMM-based repository. However, to allow this to happen, the DMM-based repository needs to be prepared. As was pointed out in Chapter 2, this is to make sure that the transfer process is allowed. This is conducted by annotating the DMM-based repository. Once this is done, eventually, each of the AB knowledge models will be deposited into the prepared repository by mapping each of them to its appropriate construct in the metamodel. This process is conducted by positioning each of them semantically. The knowledge structured in the repository then facilitates the sharing and reusing purposes. This is a semi-automatic process where a DM expert is involved to intermediate it by ensuring that the mapping between each of the AB knowledge models and each of the appropriate concepts in the repository is undertaken correctly.

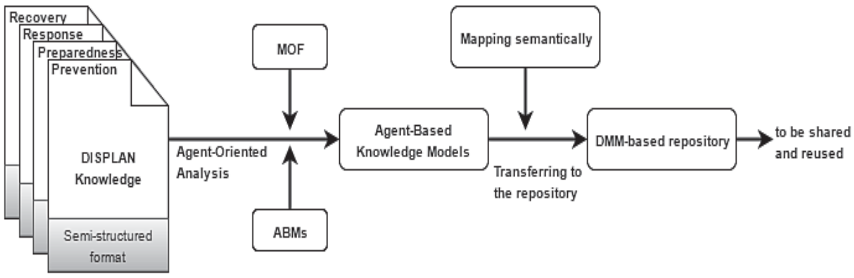


Figure 3.4 Knowledge analysis framework to be evaluated.

3.4 Phase 3: Internal Framework Evaluation

In this phase, the framework developed in Phase 2 is evaluated. Based on the DSR, an instantiation as an artefact produced from the research is implemented to ease the evaluation process. It is essentially a software prototype developed to validate the developed framework with the case study. This will be a proof-of-concept to facilitate the developed framework to be evaluated in a real case scenario. Moreover, the prototype will be a tool to conduct the evaluation processes internally of all aspects of the developed artefacts and to ease the evaluation process per se by the end users. This prototype is developed utilizing the web-based technology. Thus, essentially it can be accessed from anywhere in a connected network. This research utilizes eXtensible Mark-up Language (XML), a simple and very flexible format to model the knowledge of the DISPLAN, PHP as the most popular server-side scripting language, MySQL the most popular open source database and Apache, the most used web server application.

End users as well as the DM experts are involved in this phase for the prototype development as well as the internal evaluation process. The evaluation is conducted through a series of validation of the artefacts composing the developed framework with that particular case study. This is aimed to evaluate whether (1) each of the artefacts works as intended so as to meets the requirement specifications ranging from low to high level validations; (2) the developed framework as an integral part of the artefacts works at addressing the issues in this research. These will identify any mismatch between requirement and the design as early as possible. End users input guarantees the framework development is evaluated for all artefact dimensions with a real case study. The evaluation process, therefore, should cover all aspects categorized in their dimensions (Prat *et al.*, 2014). In this research, those identified dimensions are as follows:

- Functional dimension. This dimension covers the functionalities of the artefacts produced in this research. As indicated previously, the artefacts comprise construct, model, method and instantiation. Each of them represents a functionality accounting to each step of the developed framework. This implies that the functional dimension validation covers each of them separately and as an integral part of an instantiation. The to-be-evaluated knowledge analysis framework as shown in Figure 3.4 will validate the functionalities in each step and for the whole building block as an integral part. This dimension contributes to the internal validation which is aimed to uncover any deviation and errors of the developed artefacts. Moreover, this validation aims to identify whether these artefacts work as specified.
- Tool dimension. This dimension relates to the assisted tool created in this thesis to ease the developed framework to be evaluated. For instance, as can be seen from the to-be-evaluated framework in Figure 3.4, fundamentally there are three steps covering the whole process. They are producing the ABMs, preparing the DMM repository and transferring the models in the repository. In this dimension, a tool is developed representing and exhibiting each of the processes in each step, subsequently evaluated with a real case study. The evaluation of this dimension will take place in each step utilizing the assisted tool to help the framework to be assessed by the users. Therefore, the developed tool should be validated in representing the process in each step correctly.
- Domain dimension. In this phase, the dimension refers to the prototype evaluation of the developed framework into a case study. The case study comes from the collaborators which are the authoritative disaster agencies where this research is developed. The feedback to this validation contributes to the internal validation as it provides inputs for the framework improvements. As discussed in the literature review, the input of the framework is a semi-structured DISPLAN knowledge document. The developed framework is aimed to be used for particular type of disaster. Nonetheless, in this particular validation, a DISPLAN of flood disaster of the State Emergency Service New South Wales (SES NSW) State Australia is employed for various reasons: **(1)** This is the real DISPLAN of the authoritative agency to

combat the disaster, particular the flood, in the NSW State. The agency also is highly involved in developing the research as a collaborator; **(2)** Flood disasters, as a matter of fact, are the costliest natural hazard faced by Australia and ranked as the second deadliest disaster in Australia (Gissing *et al.*, 2010). In addition, with respect to the recent climate change studies, floods most likely will increase in the future across the world (Cavallo, 2014; Kundzewicz *et al.*, 2013); **(3)** The plan is considered as a semi-structured flood DISPLAN knowledge that is populated and written by practitioners involved in the DM for floods and can be downloaded freely from its website[2]; **(4)** It covers three out of four DM phases: Preparedness, Response and Recovery, representing pre- and post-disaster. In this activity, the chosen case study is aimed to validate that the developed artefacts work with the real case studies.

- User dimension. As mentioned previously in this research, an instance representing a construct instantiation type, is developed. This is a tool to assist the artefacts to be evaluated. In its development process, several developers are involved to evaluate internally whether the tools works and to represent the requirement specifications. An end user is highly involved and collaborates with the developers in the prototyping phase for this evaluation type. The end user in this context is the DM expert where the case study comes from. This is due to the fact that the DM expert is the one who certainly has mastered the DISPLAN and therefore he/she can justify the conversion knowledge from the plan to the ABMs to the repository and that the knowledge can be fully transferred to the repository. The DM experts are involved in the evaluation process to examine whether the developed artefact address can be categorized as the initial prototype as it, at some point, addresses the real world problem. The developers and the end user are the users in this context. The users guarantee each step of the developed framework works as specified before conducting external evaluation with another real case study. This dimension contributes to the internal evaluation.

All these dimensions are validated through the developed prototype. They all contribute to the internal validation. Essentially the prototyping and the evaluation through it are aimed to evaluate the efficacy of the initial version of the artefact. This is aimed to uncover and list the deficiencies of the initial artefact. This feedback as the input for improvement before evaluating the framework externally with another real case study.

3.5 Phase 4: External Framework Evaluation

In the DSR framework, the evaluation should be conducted rigorously and with relevance as this is the essence of the DSR (Hevner, 2007; Iivari, 2007). The feedbacks of the evaluation will be

[2] http://www.floodsafe.com.au/

used to "*refine the design further*" (Hevner, 2007, p. 4). In other words, the evaluation in the DSR is to determine whether additional iterations are required for the artefacts improvement. In Phase 3, the internal validation is elaborated through some particular dimensions. To complement that, in this phase, the external valuation is conducted with another real case study. As this evaluation type is to validate the developed framework externally, the user dimension involved in this process is the experts where the case study for this external validation is used. The DM expert also aims to represent the authoritative disaster agency where the research is aimed to be implemented in. In addition, the DM expert in involved in this evaluation type to assure the efficacy of the developed framework where it can be implemented as specified.

As indicated, in this evaluation type, the domain dimension will also be validated as this represents another real case studies to evaluate the developed framework. The case studies for this evaluation type are from both SES NSW and the SES State of Victoria, Australia. The DM DISPLAN knowledge of the agency is also a flood DISPLAN.

As elaborated previously that external validations are intended to complement the internal validation. The objective is that once the first version of the developed framework can be guaranteed to have met and worked as required through the preliminary case study (internal validation), it then gets tested to actual SES case studies. The aim of the external validations is to ascertain that the framework can be applied to various scenarios. Put simply, for other DM practitioners, it is efficient for them to adopt and adapt the existing and validated techniques rather than investing time and cost for building new ones from scratch.

To guarantee that the developed framework has been thoroughly and rigorously validated, a post evaluation for each case study will thus be managed. The framework is open for improvement after each validation with the aim for improving the framework as necessary. The ceiling for limiting the improvements is, however, that the last validated version of the developed framework is considered to have addressed the research problems.

For both internal and external validations, what follows are their key features:

1) A DM expert from SES NSW State that is highly involved in developing the flood DM knowledge this research utilises is involved in the first case study. The evaluation with the expert is conducted with the case study from the SES NSW. It is worth noting that the DM expert had been in collaborating since early of this research development. Therefore, he was involved to ascertain not only the framework development but also the tools developed for the evaluation.

2) A DM expert from the SES Victoria State is involved in the external validation. He also has been with the SES Victoria that was highly involved in developing the flood knowledge document for the organisation. Choosing an expert from each state ensures better generalisability of the framework.
3) Two honour students of information system of the University of Wollongong were also involved in the evaluation of the first case study. In particular, one of the student, he was highly involved from the early stage in the analysis and modelling phases, the tools development as the prototype produced in the research. The other student evaluated the first case study from the analysis and modelling the seven ABMs.
4) One master student of information system of the University of Wollongong was involved in evaluation from the analysis stage to produce the ABMs for the second case study.

3.6 Chapter Summary

This chapter reviewed the research based on the DSR methodology used in this thesis. This research is organized in four iterative phases. Phase 1 is the research problem identification. There are three activities which are undertaken in this phase. Phase 2 is the artefact development based on problem identification in Phase 1. Phase 3 and 4 are the evaluation phases of the artefacts. All these phases are elaborated on in corresponding chapters in this thesis. The existing and related works were compiled in Chapter 2. This is used as the foundation to define the problem gap. In this chapter, the research methodology is illustrated to show the step by step of the research activities. In Chapter 4, the development of the knowledge transfer analysis framework will be illustrated and shown. The initial version of the framework will be the output of this stage. Once the framework is developed, the next process to be followed is the evaluation. In this thesis, the evaluation stages are arranged in three chapters representing the stages of internal and external evaluations. The first validation will be compiled in Chapter 5. The output will be the feedback for the next validation. In Chapter 6, the second validation will be presented based on the feedback from the previous chapter and similarly for the third validation in Chapter 7. All the validations will be conducted with the real world case studies. Finally, Chapter 8 of this thesis presents the research conclusion and outlines the future works.

4 The Agent-Based Knowledge Analysis Framework Development

This chapter marks the beginning of a series of framework development stages based on the research problem and gap identified in the previous chapter. The framework is developed rigorously with respect to the DSR methodology. The literature review presented in Chapter 2 confirms that not only does the DM knowledge need to be analysed and modelled appropriately to disentangle all the complex characteristics but also depositing them into a representative repository are extremely challenging tasks. The issue in the modelling stage is due to the fact that the disaster is a non-deterministic event (Wex *et al.*, 2014). On the other hand, it has to comply with various constraints, such as time, organisations, as they determine that a hazard can be handled accordingly or it leads to a catastrophe (Alférez & Pelechano, 2012). The literature shows that as the DM domain characteristics have so much in common with ABM paradigm, it is not surprising that they both lend themselves to one and the other. Nonetheless, since there are no two identical disasters (Coppola, 2011), various disasters present difference knowledge elements. Although conceptually they might refer to the same meaning, on the ground they might have different elements and contexts.

In our context, to be able to address these discrepancies, in the next stage of knowledge analysis framework, the repository where the knowledge will be deposited to should be in a comprehensive structure. In other words, the repository needs to be orchestrated comprehensively encompassing those various DM knowledge concepts from the actual activities as completely as possible. The aim is to reconcile the knowledge perceptions between the one on the ground and one in the conceptual level to represent each other cohesively. As such, any related DM knowledge activity from any event in the real world is able to be mapped to its appropriate concept in the repository. Based on the literature review, metamodel-based structure, the DMM, is envisaged as the most appropriate repository to be employed. This is because not only it comprises the most comprehensive DM knowledge concepts and their relations (Al-dhaqm *et al.*, 2017), but also it is suitable for all disaster types, both natural and/or man-made/technological (Othman *et al.*, 2014). Eventually, the knowledge of the domain modelled based on ABMs is transferred to the DMM-based repository accordingly to allow it to be shared and reused by other stakeholders for the typical disasters.

This chapter strings up all those things together as an initial version of the artefact development, the Agent-Based Knowledge Analysis framework and is organised as follows: In Section 4.1, the DM knowledge analysis requirement is elaborated. This is essentially the requirement analysis prior to the framework development stages that will be elaborated. In Section 4.2, the knowledge analysis framework is presented and prescribed in details in its three main stages. These three stages are explained in Section 4.3, 4.4 and 4.5 as Stage 1, Stage 2 and Stage 3, respectively. Essentially, they are the following: (1) the stage of analysis and modelling the DM domain to be represented in the corresponding ABMs; (2) preparing the repository to allow the transferring process and; (3) the transferring process itself. Section 4.6, presents the initial version of the Agent-Based Knowledge Analysis Framework. This chapter is concluded in Section 4.7.

4.1 DM Knowledge Analysis Requirement

In this section, the requirement of the knowledge analysis framework that utilises ABMs to discretise the DM knowledge and facilitate it to be deposited into the DMM-based repository is formulated. As discussed in the Literature Review in Chapter 2, both ABM and the DMM are developed based on the MDD paradigm. In providing a bridge to the DMM, the MOF metamodelling framework abstractions and transformations can then be brought to bear to further organise and structure the DM knowledge from the unstructured sources. In other words, once the DM characteristics are analysed, the transformation process into the DMM follows the MOF framework to ensure the acquired knowledge is correctly represented and positioned (in the knowledge repository) at the appropriate abstraction layer. For example, a DM preparedness knowledge activity described in a flood management plan is as follows: "*…responsibilities to ensure the residents in the council area are aware of the flood threat in their vicinity and how to protect themselves from it*" (SES NSW Australia, 2006, p. 14). This activity is intertwined with so many other activities, for instance, who is involved in this activity, when the actions should be performed, what resources are required to support the activities, what are the pre- and post-conditions of the activity. The resolutions of these questions are essentially the knowledge elements that are useful for those who are on the planning/policy level and those who are in the real world.

On the conceptual level, these typical knowledge elements are able to be mapped to each of their corresponding concepts and relations in the DMM. In other words, the knowledge structures in the DMM-based repository represent the knowledge from the conceptual to planning/policy to real world one. Therefore, to allow this to happen, an intermediate modelling activity is required to facilitate the extraction and identification processes as to how this activity relates to the rest of the DM body of knowledge represented within a DISPLAN and implied by the DMM and MOF. The overview of the process is drawn in Figure 4.1.

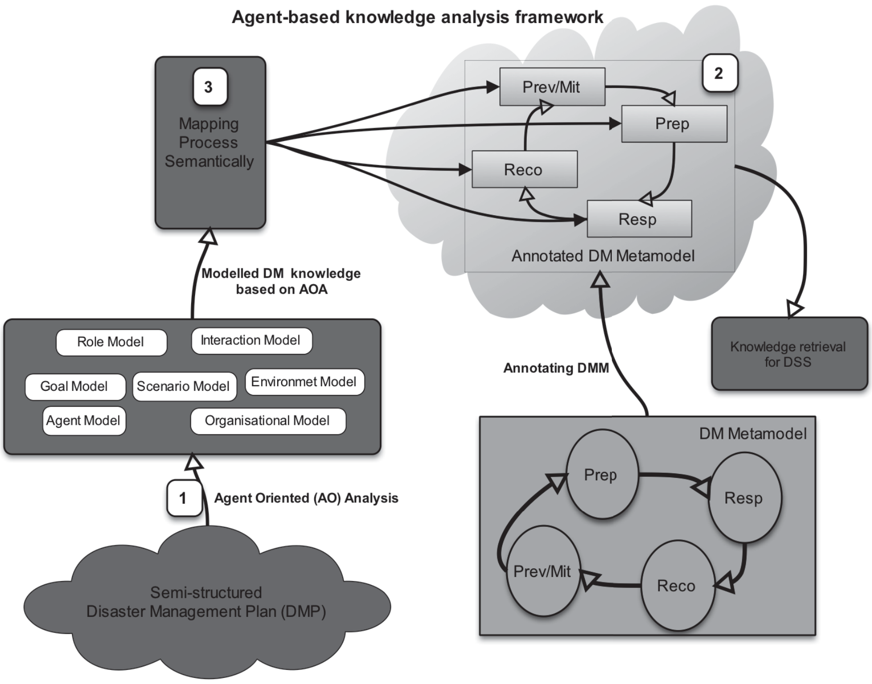


Figure 4.1 Overview of transferring process of DISPLANs into DMM-based repository.

A particular DISPLAN guides those participating in the goals described in the plan to a set of problem-solving tasks required to be pursued. The participants are typically located in specific areas of authority and have hierarchical levels of control and command. For instance, the SES NSW is the legislatively appointed combat (lead) agency to plan for and control flood, storm and tsunami DM operations. This is implemented through SES NSW Local, Regional and State organisational levels during day-to-day pre-disaster planning, and also by specific incident controllers in Incident Management Teams during response. However, even within this construct, hierarchy and control complexities exist. For example, while the NSW SES is the combat agency for flood disaster management, a NSW Police Commander will control specific tasks for which NSW Police is the controlling or lead agency. An enacted emergency plan requires all involved to be conversant with potential tasks in the PPRR cycle. This is reflected in the Total [Flood] Warning System (1) which includes, but not limited to, public information and warning, staff and volunteer mobilisation, evacuation, rescue, intelligence, and (2) situation awareness and planning strategies to protect elements (infrastructure or community) at risk.

Knowledge of the relations between various tasks and how the specific area of control overlaps with adjacent organisations, but particularly between Incident Management Teams at Local, Regional and State levels, is an essential component of success in implementing the DISPLAN. Accessing this knowledge leads to a cascade of further context awareness. It typically leads to further identification of other related knowledge, along with those tasks that might be performed in parallel, sequentially or even interleaved. In addition, in terms of performing those tasks, an agent (a person, a group of people or an agency) may play various roles and interact with many other agents. Furthermore, agents typically have different scope of control, and belong to different layers in various administrational or command and control hierarchies. Notwithstanding this, the agents still need to be able to communicate with each other to pursue a particular goal(s). As they collaborate, agents are often required to maintain their own situation awareness and need to react to changes in their environment as events unfold. In the midst of all of this, agents need to be knowledgeable of not only their goals but also of their resources and supporting systems.

The breadth and complexity of this knowledge presents a number of significant challenges for disaster managers and participating organisations, as well as the community. The NSW SES prepares and maintains some 123 individual Local Flood Plans across NSW Local Government Areas, and this involves extensive processing of flood risk data, and consultation with all organisations and participants involved, to develop the strategies in the plan. Other hazard managers, such as bushfire managers, maintain similarly large numbers of Local and Regional-level disaster plans. While there are many issues that can benefit from the work outlined in this thesis, for example, improving the inefficient maintenance of such a large connected but disparate knowledge representation currently maintained as individual Microsoft Word® documents, the critical outcome discussed in this thesis is the importance of shared understanding and ease of access to DM knowledge, roles and actions. For example, how is a participating organisation or officer, or an individual in the community, best enabled to explore and understand their role and actions in the context of a large and complex disaster management plan? A resilient community is the one which has awareness of its risk, and of strategies to deal with it, before disasters strike; it then enacts these strategies during disasters when there will be little time to try and develop this understanding for the first time from large and complex documents. Meeting this challenge is the core theme of this research.

Analysis and sharing of the knowledge above requires a systematic approach to structure the knowledge and communicate it effectively and efficiently. In particular, the analysis requires answering complex questions such as: how a goal can be identified and evaluated; how agents negotiate their priorities as they collaborate in common goal(s) such as: what specific activities agents perform as they pursue their goal(s); what resources are needed for given goals or agents and what time and resource constraints should be imposed on particular agents. The proposed framework of knowledge analysis of a DM domain within a DISPLAN, transforms the knowledge involved into a representative repository to enable sharing and reusing activities.

In this context, the MOF is also used to disentangle the fuzziness and intertwine of the complex DM knowledge by structuring the knowledge into layers. Each layer represents the knowledge in the conceptual metamodel level, planning or policy level and real activity level. For the stakeholders, this approach allows the knowledge to move up and down at any point of the DM time line. Moreover, this particular flexibility in traceable knowledge processes allow the stakeholders to effectively and efficiently identify which one is the best fit for them in any disaster activity. It is worth noting that instead of prescriptive, in this research ABMs are used as descriptive tools to analyse and model the complex characteristics of the DM domain. The ABMs are used in the analysis phase to capture and extract the knowledge out of the DM domain

In the sections that follow, the development of the knowledge analysis framework is elaborated and discussed. Essentially, it discusses the modelling activity utilizing ABMs of the DM domain, the repository and the transfer process per se between the modelled knowledge to the DMM-based repository.

4.2 Knowledge Analysis Framework

This research aims to create a bridge from the extant DISPLANs to the DMM-based repository. The MOF framework abstractions and transformations are brought to bear, to further organise and structure the DM knowledge from the extant DISPLANs. This section describes and reflects on the nature of DM knowledge sources to further justify the design decisions made in creating the framework. The initial version of the DM knowledge analysis framework is shown in Figure 4.2.

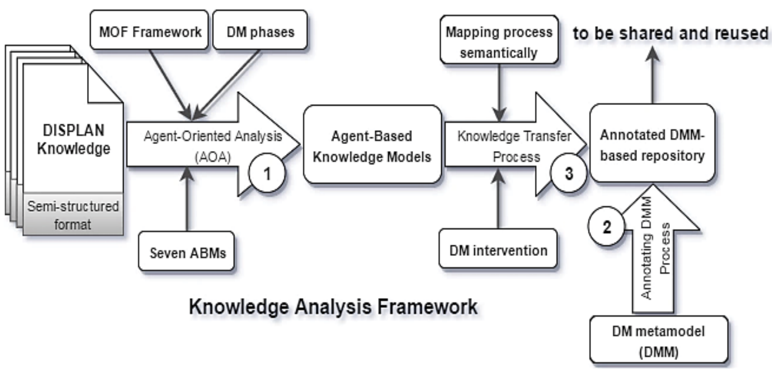


Figure 4.2 Three main stages of knowledge analysis framework.

Essentially, it consists of three stages, as follows:

1) In Stage 1 the AOA is employed to process the input. The input is the DISPLAN knowledge in a semi-structure format. The knowledge structured in the DISPLAN is formatted based on the PPRR (Prevention, Preparedness, Response and Recovery) cycle. The AOA, with respect

to the seven ABMs that are tightly coupled with the MOF, is applied to the input to produce the ABMs of the DISPLAN knowledge. The MOF in this stage functions to structure the knowledge into layers: planning/policy (M1) and real activities (M0). With this structure, the knowledge can be drilled down or rolled up through the layers to allow the stakeholders to identify the appropriate one at any timeline of the DM activities.

2) Stage 2 is the annotating of the DMM processes. As elaborated in the literature review, this constitutes the tagging processes between typical concepts developed in different domains. This aims to bridge between the knowledge models developed previously in the Stage 1 based on AO paradigm at *M0-M1* layers and the repository in the Disaster Management Metamodel (DMM) format at *M2* layer. As the AO models are developed based on AOSE, the DMM should be in AOSE metamodel (Lopez-Lorca *et al.*, 2015). All the concepts in the DMM (Othman & Beydoun, 2013) will be tagged based on the appropriate ones in the OASE metamodel (Beydoun *et al.*, 2009b). Once it is done, then the repository is ready to be used.

3) In Stage 3 the mapping processes between the knowledge in the AO models and the one in the AO metamodel is undertaken. This is a semi-automatic process as a DM expert's intervention is involved to conduct the process with respect to the semantic meaning between the two models. A DM expert intervention is involved in this stage to guarantee that each of the models from the first stage are mapped and positioned correctly to each of their appropriate concepts in the repository. At the end, a DM knowledge repository is available to support the DM decisions mechanism.

4.2.1 Stage 1: Agent-Oriented Analysis

As elaborated in the literature review, adopted ABMs are capable of representing organisational processes and activities as described in a typical DISPLAN. The models are utilized to parse and extract the complex characteristics of the DM domain. In this stage, the aim is to transform the semi-structured DISPLAN specifications into a set of ABMs to be later converted into DMM constructs. Concepts used in the AOA processes are organized in models that are accessible to many stakeholders in the DM.

In this thesis, seven AB models are identified to capture the knowledge from the DM domain: namely, the *Goal Models* (GMs), *Role Models* (RMs), *Organisational Model* (OMs), *Interaction Model* (IMs), *Environment Model* (EMs), *Agent Model* (AMs) and *Scenario Model* (SMs). They are ABMs adopted from an AOSE methodology, ROADMAP (Sterling & Taveter, 2009). They are chosen based on their capability to represent the complex characteristics elaborated in Section 2.1. At this stage, the knowledge analysis is manually performed by a knowledge engineer with a DM knowledge background (or a DM expert who has ABM analysis knowledge). The knowledge analysis tasks follow the technique commonly and widely used in KE (Caire *et al.*, 2002; Yu & Mylopoulos, 1994). That is, a knowledge engineer analyse the disaster management plans guided by the structure elements in the employed seven ABMs. For instance, the knowledge of goals, roles, responsibilities, precondition, the trigger and so forth, subsequently enables the KE to organise the DM knowledge in the elements of each of the representative models. These elements are also laid out as *M0* or *M1* elements. As shown in Figure 4.3, these ABMs are tailored overlaid with the MOF framework in the analysing the DISPLAN knowledge documents. This process produces the ABMs of DISPLAN knowledge. The details of these AOA utilizing ABMs are described as follows:

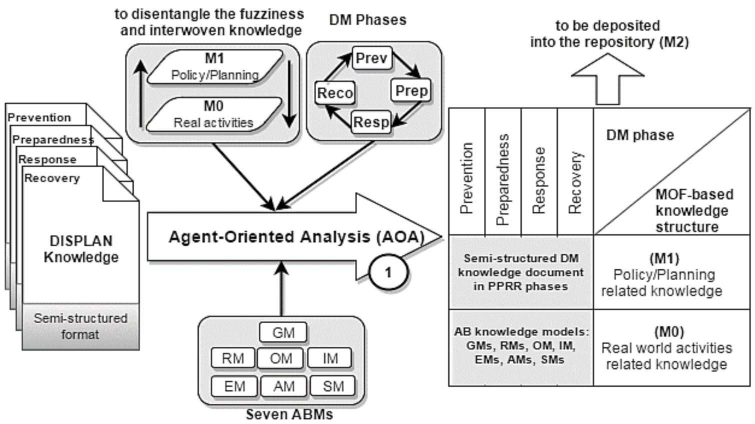


Figure 4.3 The AOA stage.

4.2.1.1 The goal models

The AOA is begun with the *goal model*. The *goal model* is the central concept that contains a main goal, sub-goals and roles that are the responsible for each of the goals. The *goal models* will be the basis to enable other models to be processed. This idea emphasizes and distinguishes that the *goal model* needs to be pursued in the first place in the AO modelling, as it describes objectives/motivations that describe conditions that need to be achieved and the roles (played by agents) that need to carry out them. This is along with the reason that identifying the goal in the DM activities is the most important thing instead of focusing on other things (Hawe *et al.*, 2012), for instance, the agencies/organisations/individual and resources. A *goal model* is illustrated in Figure 4.4. The knowledge elements in the *goal model* are as follows:

1) There are two knowledge elements, namely the goal (a main goal and its sub-goals) and the role(s).

2) The main goal is the objective that needs to be achieved in a DM activity. In a DM, there will be numerous main goals in a particular global goal. The global goal essentially represents each phase of the DM. The main goal can be drilled down into some sub-goal(s). The relation

between a sub-goal and its main goal is one of responsibility. In other words, the sub-goals(s) is responsible for the main goal.

3) The sub-goal(s) are basically the detailed description of "how-to" activities to achieve the main goal. There might be subs of a sub-goal. This means the sub of a sub-goal is the detailed description of that particular sub-goal.
4) The role(s) is an agent playing a particular role to pursue the sub-goal(s). There must be a role responsible for each of the goals.
5) The initiator is the role responsible for the *goal model* that also means it will be involved in all the goals underneath.

A *goal model* represents objectives that agent(s) persistently strives to accomplish. The main goal is the one that needs to be achieved by a set of activities represented as the sub-goals in which at least there is one role played by an agent responsible for it. In a DM, all entities (individuals/agencies/organisations) involved in all activities are required to have knowledge about their goals described in the DISPLAN. A particular goal might be pursued by more than one role(s) played by the agent(s). This means that these agents will share a responsibility of how that particular goal should be achieved. In this case, this leads the involved agents to refine each of their own responsibilities to accommodate that particular goal. The *goal model,* template tightly coupled with the MOF framework, is illustrated in Figure 4.4.

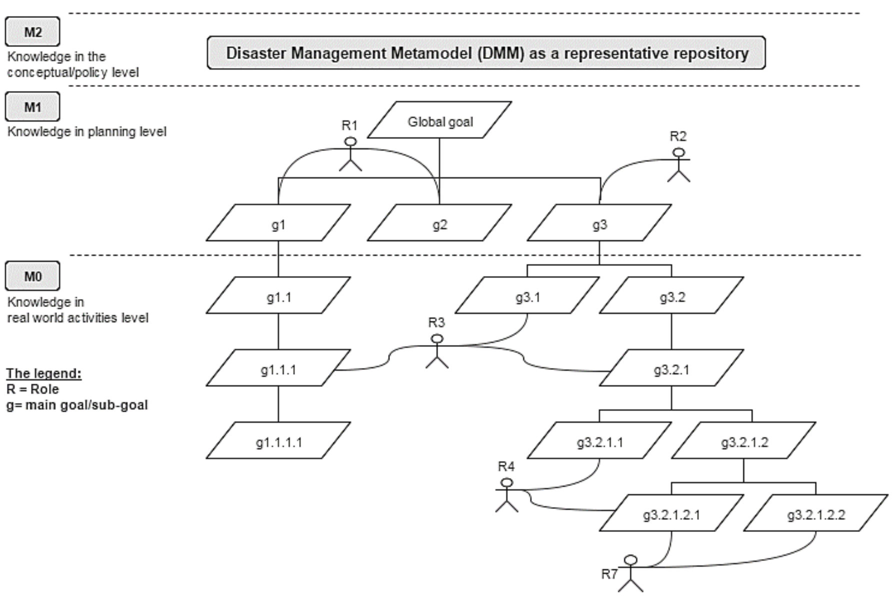


Figure 4.4 The *goal model* template structured with respect to MOF framework.

As can be seen, the global goal represents the ultimate condition in each phase of the PPRR cycle. It is automatically substituted with either Prevention (P), Preparedness (P), Response (R) or Recovery (R). In the figure, the conditions *g1*, *g2* and *g3* denote the main goals. They are objectives that need to be achieved in a particular DM cycle. In the context of the MOF, these main goals are the planning/policy knowledge represented in *M1* layer. A knowledge engineer or modeller then drills down to specify the activities of each of them in more detail. The layer underneath is the real activities represented as *M0* layer. For instance, once *g1, g2* and *g3* are identified, then the next step is to identify all the sub-goals and roles responsible for each of the main goals. In this context, the *g1.1, g1.1.1* and *g1.1.1.1* are the supporting activities to achieve *g1*. While role *R1* is responsible for each of them, *R3* is responsible to only *g1.1.1*. This informs that somehow *R1* and *R3* need to communicate and interact for the activity of *g1.1.1*. However, this particular characteristic will be discussed in other models. The *M0* and *M1,* at the end, will be transferred to the appropriate concept in the DMM-based repository represented as *M2*. This approach is conducted iteratively for all other main goals to structure other *goal models*.

4.2.1.2 The role models

Once the *goal model* is in place, the next step is modelling the role. As goals or sub-goals representing responsibilities, they all adhere to a particular role that is listed in the *role models*. Moreover, they are all listed in the model with their constraint(s). The constraint defines the boundaries of a particular role in order to perform its responsibilities. For instance, with respect to the *goal model*, for the role *R1*, all the goals (the main goal and its sub-goals), which the role is responsible for, will be listed in the *role model* as well as its constraints. An example of a *role model* is drawn in Table 4.1. This illustrates only one particular role: *R1*. Following is the description for each of the knowledge elements of the *role model* template drawn in Table 4.1, as follows:

1) The role ID is the unique ID for each role and is obtained from the roles in the *goal model*.
2) The role name is the name of the role played by an agent.
3) The description is an explanation of the role played by an agent.
4) The responsibility is a detailed list if activities that are adhered to in the role obtained from the sub-goal(s) elements(s) in the *goal model*.
5) The constraint(s) is a long-term condition defining the role's entities (organisations/agencies/individuals).

As drawn in Table 4.1, the role *R1* is listed along with its responsibilities and constraints.

Table 4.1 The *role model* template structured with respect to MOF.

DMM-based repository		M2
Role knowledge		**MOF layer**
Role ID	R1	M1
Role Name	Real name of role R1 (for instance, BoM, Policy, etc.)	
Description	The responsibilities of the [Bureau of Meteorology] agent playing the role in a particular disaster event of a particular DM phase.	
Responsibility	g1 g1.1 g1.1.1 g1.1.1.1 g2	M0
Constraint	R1 entity constraint	

The MOF framework structures the *Role ID* as *M1,* as it describes the identity knowledge of the role, whereas the *responsibilities* and *constraints* are structured as *M0,* as both knowledge elements represent the knowledge in the real domain activities. Both *M0-M1* layers will later be transferred to the corresponding concept in the repository at *M2* layer representing the role *R1*. The same approach is conducted iteratively until all the roles are analysed and structured through *role models*.

4.2.1.3 The organisation model

The next step in the AOA is modelling the organizational relationships of roles involved in the DM activities. The relationships of the roles played by agents inform a hierarchy level of the agent's need to communicate, coordinate and negotiate with each other, whenever necessary. This knowledge is modelled in the *organisation model*. This *organisation model* of agents playing roles and their relationships are drawn in Figure 4.5. These roles are identified based on the *goal model* in Figure 4.3.

The *organisation model* represents how an entity is approached by others. This knowledge informs how the entities communicate and negotiate with each other in pursuing a particular activity. For instance, in managing an aircraft to be used by SES NSW in an evacuation, rescue or reconnaissance flood disaster activity (SES NSW Australia, 2010), the local controller can only perform the operation with the aircraft control and allocation from the SES division headquarter as a higher hierarchy administration level. This implies that to be able to have access to the aircraft, the SES NSW Local Controller needs to identify the hierarchy level types to be contacted for obtaining authorisation and accessing the resources. Following is the description of the knowledge elements of the *organisation model* template, as follows:

1) The roles in the *organisation model* are obtained from the *goal model*.

2) The relationships describing the hierarchy levels of the roles are identified from the *goal model*. It defines how the roles are coordinated, communicated and negotiated with each other since they are different entities with different levels of authority in the hierarchy involved in the DM activities.

Essentially there are only two relationship types that can describe the organisation knowledge of the involved roles; they are: *Controls/isControlledBy* and *isPeer*. The *Controls/isControlledBy* defines that of the interrelated roles, one of them is in a higher administration level that therefore controls the other. In other words, the one is controlled by the other. The relationship type *isPeer* means both interrelated roles are colleagues to each other. As depicted from Figure 4.5, the role *R2 Controls R7* and *isPeer* with *R5* and *R6*. The figure also informs that the role *R4 isControlledBy* role *R2* (or in other words the role *R2 Controls* the *R7*). A case in point in this context is for instance, the relationships between the SES NSW, SES Murrumbidgee and NSW Police (SES NSW Australia, 2010). While the SES NSW *isPeer* to the NSW Police, as they are the organisations in the state level, the SES NSW controls SES Murrumbidgee, as they are the same but different hierarchy level of SES. One of them is in the state level, the other is in the Region level.

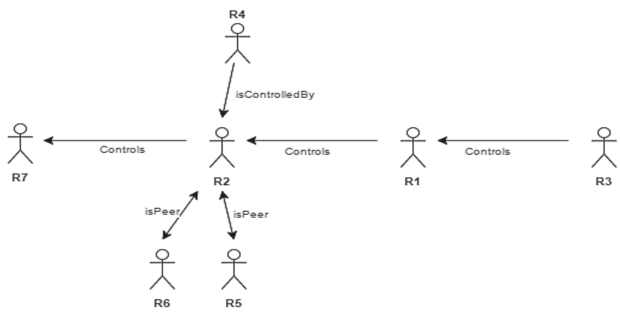


Figure 4.5 The *organisation model* template structured with respect to the *goal model*.

This typical knowledge informs all the involved entities of the hierarchy and authoritative levels, whenever they are required to communicate to and negotiate with. In the case that a disaster escalates to regional or federal level, the organisation knowledge that has been available in place would be beneficial for the communication issues, as this will decrease the response time. This is due to the fact that all the roles involved in the activities have a same standing ground to be able to contact others, whenever necessary in pursuing DM activities. This is a critical element as the DM is a collaborative activity to be conducted by entities with different backgrounds and sovereignties. The way this *organisation model* knowledge is incorporated with the MOF framework is defined in Table 4.2. The roles played by agents are structured as *M1* and the organisation knowledge regarding their relationships is structured as *M0*. The *M2* in the table shows that the typical knowledge will be converted to its appropriate metamodel concept at *M2* layer in the transferring process.

Table 4.2 The *organisation model* structured with respect to MOF framework.

DMM-based repository					M2
Organisation knowledge					**MOF layer**
Role A		**Organisation knowledge**	**Role B**		
Role Name	Agent plays Role A	*Controls/ isControlledBy/ isPeer*	Role Name	Agent plays Role B	M1
Description	Description of R1		Description	Description of R2	M0

4.2.1.4 The interaction models

Subsequently, to what extent the roles played by agents involved in a complex domain activity interact are described in the *interaction models*. The *interaction model* represents in which particular goal/sub-goal of two or more entities interact with each other in pursuing particular goals. For instance, with respect to the SES NSW flood DISPLAN, in the context of hierarchy level the SES Local Controller and the SES Division Headquarter will be interacting each other in pursuing these particular goals: "*managing, operating and allocating the aircraft for either evacuation or rescue or re-supply or reconnaissance or emergency travel*" (SES NSW Australia, 2010, p. 25). The description of the knowledge elements of the *interaction model* is described as follows:

1) The role elements are obtained from the *goal model*, representing the roles.
2) The activity element is basically the *RolePursuesGoal* knowledge element. The roles are interacted, communicated and negotiated between each other in this objective. This is obtained from the *goal model* representing the sub-goals.
3) The *interaction model* template draws only the activity knowledge element in which there is more than one role involved.

Thus, while the *organisation model* describes the hierarchy level knowledge of the agencies/organizations/individuals, the *interaction model* models the knowledge toward which goals these agencies/organizations/individuals interact to achieve. This knowledge fundamentally informs the motivation in which the roles should be communicated for. This is illustrated in Figure 4.6. As can be seen from the figure, the role *R1* and *R3* are interacted in pursuing the goal *g1.1.1*. Moreover, the *R2* and *R3* are interacted in pursuing the goals *g3.1, g3.2* and so forth.

As discussed, the knowledge in the *interaction model* is also structured in the MOF layers to disentangle between the planning and real world activities. This is drawn in Table 4.3. As can be seen the knowledge describing the interaction between roles in pursuing a particular goal is a *rolePursueGoal* element. Thus, for instance, the roles *R1* and *R3* interact with each other because they both pursue the sub-goal *g1.1.1*. The knowledge engineer adopts this process iteratively to complete the other *interaction models*.

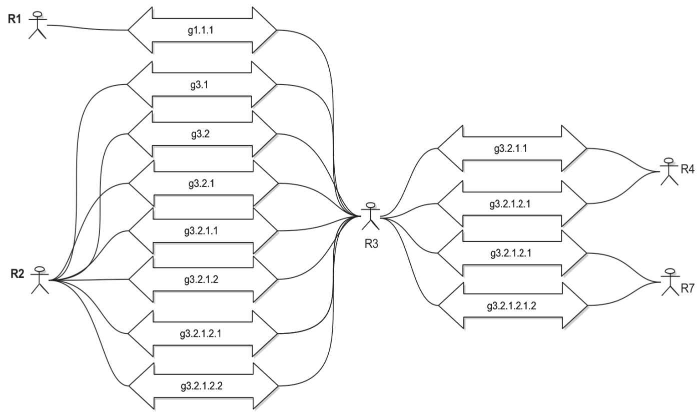


Figure 4.6 An *interaction model* template.

Table 4.3 The *interaction model* structured in table with respect to MOF.

DMM-based repository			M2
Interaction knowledge			**MOF layer**
Role A	***rolePursueGoal***	**Role B**	M1
Agent plays Role A	g1.1.1	Agent plays Role B	
Description of Role A	Description of g1.1.1	Description of Role B	M0

4.2.1.5 The environment models

In a DM activity, any resource required by agents-play-roles to pursue a particular goal(s) has to be identified. Although it is not part of the system however, it is essential to accomplish the activities as it is used by role(s) and required to accomplish the DM identified objectives. This typical knowledge is structured in the *environment model*. This model essentially describes an agent as situated in an environment (Jennings & Wooldridge, 2001; Wooldridge & Ciancarini, 2001). In our context, all the resources used by entities involved in the DM activities will be analysed and modelled in this particular model to support the roles in pursuing the goals. The description of the knowledge elements of the *environment model* that is drawn in Table 4.4 is elaborated as follows:

1) The environment entity ID informs the unique ID for each environment knowledge element.
2) The name and description inform the type of the environment knowledge and its description.

3) All these elements inform the knowledge required to structure the complete and informative environment element.
4) The roles involved inform the role using the environment knowledge to pursue the goal(s). This is obtained from the *role model*.

In Table 4.4, the environment knowledge elements are shown with respect to the MOF framework. The model elements describe the detail specification of a particular environment listed in the *environment model*. For instance, if the environment knowledge is about a list of media communications needed in a particular activity then the elements inform the details of the media communications, for example, the media types which could be in print or online, the contact person of the media to be contacted, telephone number or email to be contacted and so forth. All the knowledge related to the media communications would be identified from the planning/policy for the planner or policy maker to the real world knowledge for people on the ground. The involved role elements in the model describe what roles will use this particular environment knowledge element in pursuing a particular activity. The higher abstraction knowledge of the environment is categorized by the MOF as *M1* layer and the elements describing the details including roles involved of are in *M0* layer. The knowledge structured in *M0-M1* layer at the end will be combined with its correspondent *M2* layer in the repository as the complete knowledge structure. For the rest of the other *environment models*, this approach will be iteratively processed to complete them.

Table 4.4 The *environment model* template structured with respect to MOF.

DMM-based repository			M2
Environment knowledge			**MOF layer**
Environment Entity ID	E1		M1
Environment Name	Real name of environment E1 (for instance, List of media communications)		
Description	The environment used by particular roles played by agents in a particular [Flood] disaster event of a particular DM phase.		
Attributes	#	Unique number distinguishing inputted data	M0
	Attribute1	Meta-attribute1	
	Attribute2	Meta-attribute2	
	Attribute3	Meta-attribute3	
Roles Involved	R1 R2 R3		

4.2.1.6 The agent models

Having identified the *environment model*, the next to be discussed is the *agent model*. This model synthesises all the activity elements that an agent will strive for to achieve its main goals. This model is drawn from the characteristic that an agent is not only reactive, but also proactive (Winikoff & Padgham, 2013; Wooldridge & Jennings, 1995). The reactiveness is regarded as the consequences of the triggers from the oscillating environment while proactiveness refers to objectives in which agents play roles to pursue them regardless of the external circumstances (Padgham & Winikoff, 2004). In the *agent model*, each main goal is structured as an objective to be achieved. All the sub-goals for each main goal that a particular agent is responsible for are listed.

The *agent model* template is described in Table 4.5. As can be seen, the agent is *A1*, the objective/main goal to be pursued is *g1* and the *actions* which support that particular objective are *g1.1*, *g1.1.1* and *g1.1.1.1.* The *trigger* is the element informing as to when an agent has to react appropriately as the consequence of it sensing the environment fluctuations. Therefore, the agent pro-acts by taking the initiative with corresponding actions. In our context, learning from the best practice knowledge is the guidance for these activities. For instance, once the information about a dam failure warning is received by the SES Local Controller, all the authoritative individuals, agencies and organisations will be contacted regardless of the location and severity of the warning to anticipate the disaster (SES NSW Australia, 2010). Each of these agencies subsequently takes the necessary actions based on the existing knowledge as guidance for them to follow. Following is the descriptions of the *agent model* elements, as below:

1) The element name is the agent's name representing the agent that plays a role and it is obtained from the *role model*.
2) The reference is the role ID's reference from the *role model*.
3) The activity name defines a list of the activities of the agent playing a role in pursuing the main goal.
4) The Activity name element is the name of the activity.
5) The functionality element describes the main goal that needs to be achieved in the activity.
6) The trigger is an event that will likely generates those particular activities.
7) The action(s) is a set of activities conducted in the role played by the agent to pursue the functionality. The action(s) is the sub-goal(s) obtained from the *goal model*.
8) The environment entity is the environment used by the role to achieve the main goal and it refers back to the appropriate environment knowledge in the *environment model*.

As can be seen from the Table 4.5, the more abstract knowledge is structured as *M1,* based on the MOF framework. They are the agent identities, namely: *agent ID*, *agent name* and *role* the agent plays. In the lower abstraction layer, the *activity* and *environment entities* are defined as

M0. In the activity part, the *name* and *functionality* of the activity are the main goal that an agent strives for; the *triggers* and the *actions* that the particular agent needs to carry out are described.

Table 4.5 The *agent model* template structured with respect to MOF.

DMM-based repository				M2
Agent knowledge				**MOF layer**
Agent ID	A1			M1
Agent name	Agent A1 playing a particular role			
Role played	Role played by agent A1 (for instance, R1)			
Activity		Activity Name :	g1	M0
		Functionality :	g1	
		Trigger :	T1 T2	
		Action :	g1.1 g1.1.1 g1.1.1.1	
Environment Entity	E1, E2, E7, E8			

These are the knowledge in the real world activities. Still in the *M0* layer, environment knowledge defined as *environment entity* element is also part of it, as it describes the resources an agent needs in pursuing the goals. As for environment knowledge details, it will refer to the *environment model* with the same identity (E1, E2, etc.). This approach is carried out iteratively to complete the rest of the other *agent models*.

4.2.1.7 The scenario models

The last one of the ABMs to be analysed is the *scenario model*. The knowledge elements in this model are similar to those in the *agent model*. However, the *activities* in the *agent model* focus on one particular agent only whereas, in the *scenario model* all the activities to achieve a particular objective are laid out along with the roles responsible for each of the activities and the resources needed. These knowledge elements are all listed in a way they can be understood holistically and comprehensively particularly, in a decision support system mechanism. Thus, in the *scenario models* the condition whether those activities should be performed parallel, sequentially or interleaved matters. Therefore, these typical conditions determine how the activities in the *scenario model* will be performed.

Nevertheless, similar to *agent models*, emphasise of the *scenario models* is also for helping a story-telling process for decision making in the DM activities. The knowledge elements in the *scenario model* are bound together to ease the stakeholders unfolding the knowledge in a real scenario context. Therefore, in the *scenario model*, *pre-* and *post-conditions* are also provided in this model to frame the conditions correctly before and after conducting the objective. In addition to informing who is/are responsible for and the resources required in pursuing that particular objective, the *roles* and the *environment* knowledge are provided in each of those activities. The *scenario model* is shown in Table 4.6. The element's descriptions of the *scenario model* are as follows:

1) The scenario ID is the unique identity that distinguishes one scenario from another.
2) The name and goal are the main goal obtained from the *goal model*.
3) The initiator is the role that is responsible for initiating this particular scenario and therefore responsible for the main goal.
4) The trigger is the event that spurs a particular activity.
5) The pre-condition and post-condition are the conditions before and after pursuing a particular goal.
6) The condition is aimed to define whether the activities will be conducted in parallel, sequentially or interleaved. This condition is determined by a DM expert if there is no related knowledge explicitly expressed in the document regarding it.
7) The activities describe a set of activities to pursue the goal. They are obtained from the sub-goals in the *goal model*.
8) The roles define all the roles that are involved in a particular scenario. Each of them is designated to each of the activities responsible for achieving the main goal.
9) The environment entity defines the environment knowledge used by those role(s) in each of the activities to achieve the main goal.

Table 4.6 The *scenario model* template structured with respect to MOF.

DMM-based repository					M2
Scenario knowledge					**MOF layer**
Scenario		S1			M1
Name		g1			
Goal		g1			
Initiator		R1			
Trigger		T1 T2 T3 T4			M0
Pre-condition		Pre-conditions			
Post-condition		Post-conditions			
Description		Description of g1			
Condition	*Step*	*Activity*	*Role*	*Environment Entity*	
Sequential/Interleave/Parallel	1	g1.1	R1	E1,E2	
	2	g1.1.1	R1,R3	E1,E2	
	3	g1.1.11	R1	E1,E2	

In this model, with respect to the MOF framework, the high level knowledge such as the scenario name, the main goal to be achieved, as well as the initiator who is responsible to achieve a particular goal is structured in *M1* layer. The rest of the knowledge elements are managed in

M0 as they define the knowledge in the real world activities. These typical knowledge elements should be embraced by the stakeholder in a DM activity without requiring any deductive process. This is critical, as in a DM the longer time is spent, the more probable is the hazard turns out to be a disaster. Therefore, the necessity to analyse and structure the DM knowledge comprehensively and holistically is extremely urgent. A knowledge engineer processes this modelling task iteratively with the DISPLAN knowledge input to complete the *scenario models*.

At the end, all these seven ABMs are tailored together with MOF framework to process the DISPLAN knowledge as the input document structured in each of the DM phases. These three components essentially construct three-dimensional (3D) ABMs of DISPLAN knowledge. As can be seen in Figure 4.7, the ABMs construct the Y axis, while DM phases and MOF framework construct X and Z axis respectively. Each of the cubes represents these three knowledge elements which will then be mapped to the corresponding DMM concepts in *M2* layer. This 3D knowledge structure allows each of the knowledge cube to be identified comprehensively and holistically. For instance, what identified knowledge is for, in which level/to whom it is aimed for, and in what DM phase it is used for. This structure allows a knowledge engineer to focus only one cube at a time for analysis, modelling and transferring processes to subsequently completing the whole 3D structure. The knowledge engineer will then iteratively follow the same approach in the transferring process for the cubes one by one until all of them are converted into the DMM-repository completely. The converting process will be elaborated in Stage 3.

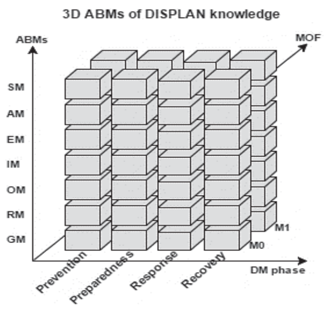


Figure 4.7 A three-dimensional (3D) ABM of DISPLAN knowledge structure.

4.2.2 Stage 2: Annotating DMM concepts with FAML metamodel concepts

Having discussed the analysis and modelling of the knowledge, this stage aims to define the repository, where ABMs resulted from the Stage 1 will be able to be deposited to. This research employs the DMM (Othman & Beydoun, 2013) to serve as a representative knowledge repository for DM activities. Essentially, this stage prepares the structure of the repository to receive the ABMs from Stage 1. This stage readies the repository to receive the ABMs into the DMM constructs in the transfer process. The repository is structured using the metamodel, the DMM, which was synthesized using 89 existing DM models and covers all essential and relevant concepts across all those DM models (Othman *et al.*, 2014). Nonetheless, as indicated in the previous chapter, this thesis does not discuss the DMM development; rather it adopts it as a representative repository.

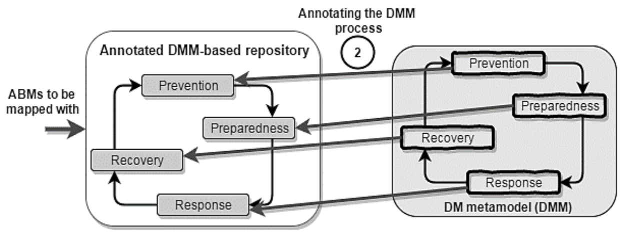


Figure 4.8 Annotating process of the DMM-based repository.

The general picture of the idea in this stage is illustrated in Figure 4.8. The idea presented in the figure is essentially the basis for providing a mapping mechanism between the knowledge elements of the models from Stage 1 and the DMM constructs. As can be seen, all the DM phases are annotated. This implies that all the concepts in each of these phases are annotated. Eventually, these processes result in a complete annotated DMM-based repository. As elaborated in Chapter 2 regarding the annotating process, in our context, fundamentally it is a process to extend all the DMM concepts by tagging/annotating a piece of information to each of them. The aim is to shield their complexities from the external examination, particularly in the interoperability issues without modifying their originalities.

The annotating process of the DMM should be consistent with the MOF framework. To be able to ensure this consistency, in this research, the corresponding AB metamodel of AOSE, FAML (Beydoun *et al.*, 2009b) is employed. Considering the adopting of FAML as the AOSE metamodel benefits this research in two ways: (1) In the Stage 1, the knowledge in the real world layer, *M0*, is analysed utilizing the ABMs from the AOSE paradigm and structured as *M0-M1 in each of the representative models*. Therefore, for the metamodel, it should also be in the AOSE paradigm for consistency. In the literature review, the FAML metamodel is justified as the most comprehensive metamodel in its completeness compared to others. Therefore, this particular metamodel is used in our context for the annotating process; (2) FAML metamodel is widely recognised as the most complete AOSE metamodel as it is developed and synthesised based on the prominent existing AOSE metamodels. As such, in this context, there is no need to build a generic AOSE metamodel from scratch for this purpose, but focusing on accelerating the framework development.

In the process, each of the DMM concepts is annotated with each of appropriate AOSE metamodel concepts. This is aimed to create a representative DMM-based repository, where the knowledge structured in the ABMs (*M0→M1*) can be deposited into it (*M2*) accordingly.

Subsequently, the process facilitates the sharing and reusing processes. It is worth noting that this annotation process is a one-off process for all concepts in the DMM with their appropriate annotation concepts from the AOSE metamodel constructs. However, a knowledge engineer can always revisit to calibrate the process whenever required. In the annotating process, a knowledge engineer is involved to pin point each of the concepts in the DMM and the representative one in the FAML metamodel construct. Table 4.6 shows some DMM concepts (Othman *et al.*, 2014) in the Response phase as an example for this mapping process.

On the other side, the corresponding FAML metamodel concepts are shown in Table 4.7. As indicated, in the process each of the DMM concepts is mapped with its representative FAML metamodel concept by judging their semantic similarities. All the FAML metamodel concepts in Table 4.7 represent each of the ABMs in their higher abstraction layers except *organisation model* and *interaction model*. In the AOA in Stage 1, the *organisational model* is aimed at representing the hierarchy level of all roles played by agent(s) to be able to communicate, coordinate as well as negotiate with each other accordingly.

Table 4.6 DMM constructs and their semantic descriptions in Response phase (Othman *et al.*, 2014).

No	DMM Concept in Response phase	Description
1	*ResponseTask*	A task and responsibility that needs to be accomplished by Response team.
2	*ResponseGoal*	A description of the end state of response phase where the organization wants to be at the end of the activity, program, or other entity for which the goal was defined.
3	*Incident*	An event, accidentally or deliberately caused, which requires a response from one or more of the statutory emergency response agencies.
4	*Communication*	A system of dissemination of any kind of emergency information using a variety of means to people and organizations during disaster.
5	*EmergencyManagement-Team*	An organization and management of resources and responsibilities for addressing all aspects of emergencies, in particular preparedness, response and initial recovery steps.
6	*InformationManagement*	A process that collects, analyses, formats and transmits data and information during an incident
7	*Rescue*	A process of locating and recovering victims and the application of first aid and basic medical assistance as may be required.
8	*HumanitarianAid*	A material or logistical assistance provided for humanitarian purposes, typically in response to an event or series of events which represents a critical threat to the health, safety, security or wellbeing of a community or other large group of people, usually over a wide area.

This implies that by having this knowledge, each role played by an agent knows how to approach and interact with other roles played by other agents in the different hierarchy levels, whether they are in the same level, lower level or higher level. In the DM context, the role played by an agent might also belong to a different administration context. For instance, a disaster can escalate from local to national or international boundaries or can occur encompassing more than one administration city. This means agents involved in the activities will automatically increase in number and variety. This implies that the communication issues of these entities are challenging. However, once this particular knowledge is captured in the *organisational model*, the need to communicate can be initiated accordingly.

To be able to describe the hierarchy level among agents involved in the DISPLAN as described in the *organisation model,* then domain properties of the agents are added as *isPeer*, representing agents in the same hierarchy level, *Controls* and *IsControlledBy* represent an agent controls another or is controlled by others. Interactions in the *interaction model* between agents to pursue goal(s) are described by adding the relations *ParticipatesIn* to represent an agent participating in a particular activity, or in pursuing the activity, it *Involves* agent(s). For instance, if an agent A plays a role X and an agent B plays another role Y where they interact for a goal P, then both agent A and B are described using the relationship *ParticipatesIn* to achieve goal P. In other words, goal P *Involves* agents A and B.

Table 4.7 Annotating process between some DMM concepts of Response phase (in Table 4.6) to each of their appropriate FAML metamodel concepts.

DMM Concept in Response phase	FAML metamodel Concept	Abstract syntax (semantics) represent both constructs
ResponseTask	*<<Role>>*	Represents a set of capabilities to perform by agent to achieve the goal(s)
ResponseGoal	*<<Goal>>*	Represents certain conditions that needs to be achieved by the system
Incident	*<<Event>>*	Defines a situation change that influences a significant change of an agent to respond to the situation
Communication, *HumanitarianAid*	*<<EnvironmentEntity>>*	Represents any resources required to perform the tasks
Emergency-ManagementTeam	*<<Agent>>*	A highly autonomous, situated, directed and rational entity and can play one or more roles
Information-Management, *Rescue*	*<<Activity>>*	An organized collection of action specifications to be performed to achieve the goal(s), including any pre- and post-conditions

There are 92 DMM concepts (Othman *et al.*, 2014) across all PPRR phases that are annotated (21, 25, 25 and 21 concepts respectively in each DM phase). The *Rescue* concept, for example, is defined as follows: "*The process of locating and recovering victims and the application of first aid and basic medical assistance as may be required*" (Othman *et al.*, 2014, p. 257). This is a set of activities to be undertaken to maintain the skills of DM stakeholders. This consists of a set of activities, hence, the corresponding concept from the AOSE metamodel is <<*Activity*>>: "*Describes a set of activities to be performed to achieve the goal(s)*". Therefore, the knowledge engineer annotates concept *Training* in DMM with the <<*Activity*>>.

Another example is an *EmergencyManagementTeam* defined as follows: "*A group of all agencies with a role in incident management that provides interagency coordination for domestic incident management activities in a non-emergency context to ensure the proper level of planning, training, equipping and other preparedness requirements within a jurisdiction or area*" (Othman et al., 2014, p. 258). This concept describes a set of roles played by an agent(s) to pursue a goal(s) in a DM activity. As a role representing a set of capabilities played by an agent, the appropriate AOSE concept in the metamodel for P*reparednessTask* is <<*agent*>>: "*Represents an entity that having certain properties and can play one or more roles*". Therefore, a knowledge engineer annotates the *PreparednessTask* to the <<*agent*>> in the DMM. Of all the DMM concepts, we identify that essentially they can be classified in to some 6 (six) FAML metamodel concepts as we identify in Table 4.7. The complete annotated DMM-based repository for Preparedness and Response phases are drawn in Figure 4.9 and 4.10 respectively. These two figures show all the DMM concepts and each of their corresponding FAML metamodel concepts are fully annotated.

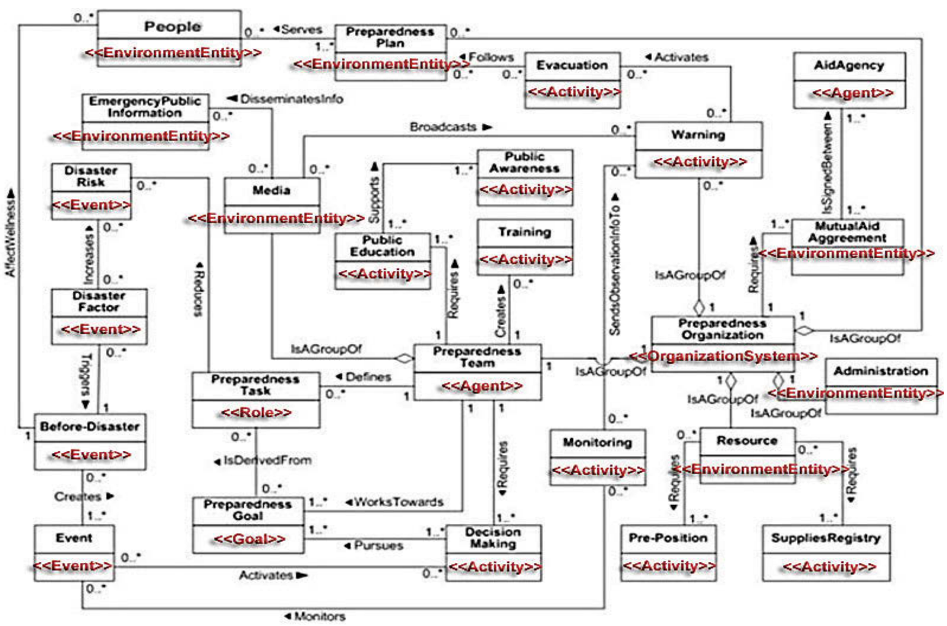


Figure 4.9 The annotated DMM-based repository in Preparedness phase.

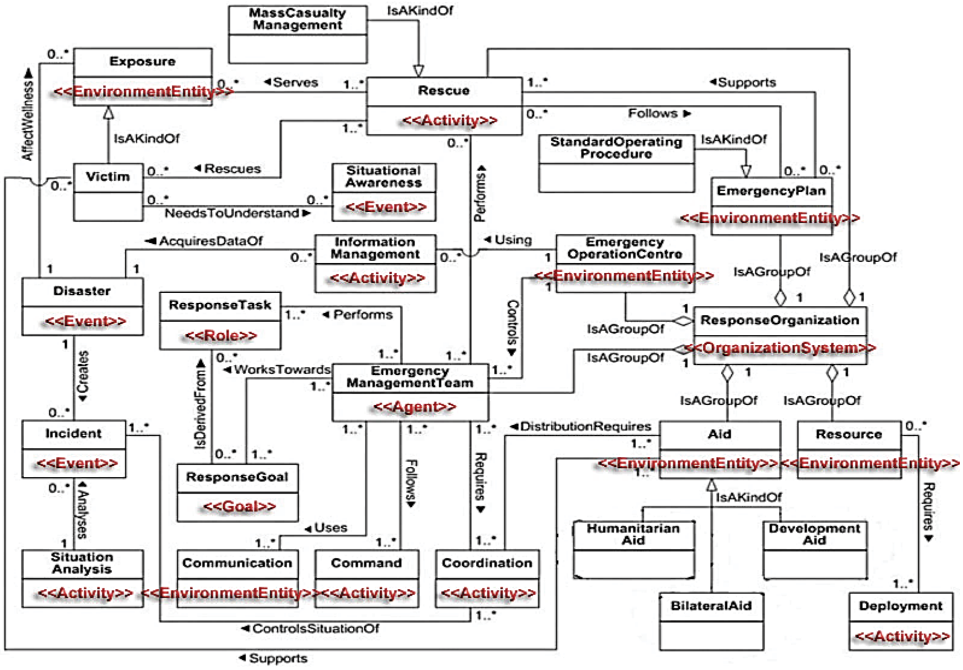


Figure 4.10 The annotated DMM-based repository in Response phase.

As in Stage 1, fundamentally this annotating process comprises a three-dimension knowledge concept, namely the *M2* layer of MOF, as it only discusses the DM concepts across all DM phases and the seven ABMS. Therefore, this moulds a three-dimensional (3D) annotated DMM-based repository. This is illustrated in Figure 4.11. The repository is now ready for knowledge transferring that will be elaborated on in Stage 3.

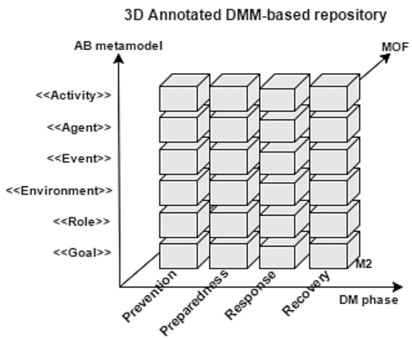


Figure 4.11 A three-dimensional (3D) annotated DMM-based repository.

4.2.3 *Stage 3: Transferring the ABMs into the annotated DMM-based repository*

In this stage, the ABMs of DISPLAN knowledge acquired from the AOA in Stage 1 are transferred into the annotated DMM-based representation. This transferring process is constructed in a semi-automated process, as it still requires a DM practitioner intervention to be able to map the depositing process semantically. This process is shown in Figure 4.12.

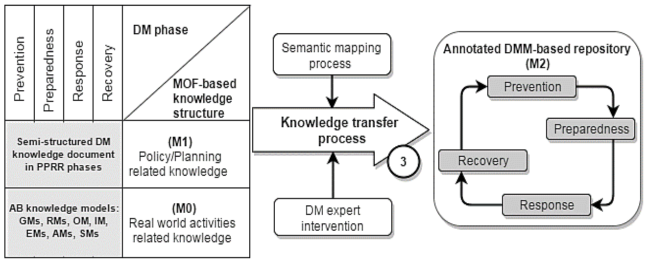


Figure 4.12 Knowledge transfer stage of ABMs to the representative repository.

As can be seen in the figure, essentially the transferring process is a model-to-model transformation. The real domain (*M0*) that is being modelled (*M1*) is transferred into the metamodel (*M2*). In this context, the DISPLAN knowledge structured in the ABMs is transformed to the annotated DMM-based repository. With respect to the MOF framework, the knowledge in the ABMs is in the *M0-M1* layers and subsequently it needs to be transferred into the *M2* layer. Both ABMs and the repository are structured in 3D formats. Each of the ABMs will be positioned and mapped to each of the appropriate concepts in the DMM-based repository. This process is conducted by examining their semantic meanings.

In this research, the involvement of a DM expert in the semantic meaning examinations is due to the fact that there is no system that can replace a human's capability in a decision making mechanism. In this research, the objective is to develop a framework for knowledge analysis that can contribute to address knowledge sharing and reusing issues in DM resilience endeavours. These are the real issues of the current DM researches (Allen *et al.*, 2014; Bunker *et al.*, 2015; Dorasamy *et al.*, 2013; Fikar *et al.*, 2016; Rivera *et al.*, 2015; Wang & Hsiao, 2014). For the future work, a fully automatic semantic mapping process will be sought.

As illustrated in Figure 4.12, the process in this stage is the foundation of our knowledge analysis framework. Eventually, this contributes in the Decision Support System (DSS) of the DM. It transforms the user knowledge to its metamodel (*M0-M1-M2*, with respect to MOF framework). By adopting the MOF framework, the fuzziness and intertwined knowledge of DM can be disentangled and pinpointed to which abstraction layer it belongs. The exemplar of it is illustrated in Table 4.8. In the table, for instance, the DM knowledge (*M0*) (left column) is analysed based on each of the appropriate seven ABMs (*M1*) (mid column) and these models intermediate the knowledge to be mapped to their metamodel (*M2*) concepts (right column). The knowledge from the DM document regarding the specific know-how of the DM activity is analysed and structured into the corresponding ABMs. Subsequently, the models are mapped into the 92 annotated DMM-based concepts in the PPRR phases where appropriate. As in the table, the ABMs of DM knowledge will be mapped to the six FAML metamodel concepts representing the 92 DMM constructs. For instance, the knowledge related to objectives that need to be achieved in Response phase is modelled and structured in the *goal model*. In the DMM-based repository, the model is mapped to the corresponding construct <<*Goal*>>. As there is only one possible concept in the repository, where the *goal model* is able to map with, this mapping process can be undertaken automatically. Therefore, the *goal model* will be transferred to <<*ResponseGoal*>> (see Table 4.8).

Table 4.8 Mapping process between the ABMs of DISPLAN knowledge and their appropriate annotated DMM-based concepts in Response phase, an example.

Related DM knowledge (M0)	**ABM (M1)**	**Appropriate annotated DMM Concept (M2)**
Knowledge related to objectives that need to be achieved in Response phase	*Goal model*	*<<Goal>>: ResponseGoal*
Knowledge related to activities to manage and disseminate information in an incident	*Scenario Model*	*<<Activity>>: InformationManagement*
Knowledge related to rescue activities	*Scenario Model*	*<<Activity>>: Rescue*
Knowledge related to an agent pursuing a particular goal by playing a particular role	*Agent Model*	*<<Agent>>: EmergencyManagement-Team*
Knowledge related to agents playing particular roles	*Role Model*	*<<Role>>: ResponseTask*
Knowledge related to communication tools as supporting systems to the activities	*Environment Model*	*<<EnvironmentEntity>>: Communication*
Knowledge related to humanitarian aid as supporting systems to the activities	*Environment Model*	*<<EnvironmentEntity>>: HumanitarianAid*

Nonetheless, another example in this stage shows that this mapping process is not processed directly. For instance, the knowledge related to communication tools as supporting systems in the Response phase is modelled to the corresponding ABM, namely *environment model* (see Table 4.8). In the DMM-based repository, the model is represented by the construct <<*EnvironmentEntity*>>. Nevertheless, as there is more than one <<*EnvironmentEntity*>> representing difference concepts in the repository then the DM expert is needed to be involved to examine the most appropriate one (*Communication* or *HumanitarianAid*, see Table 4.8) to be mapped to the *environment model* representing the knowledge from the real world domain. The examination process is undertaken by judging the semantic similarity of the two concepts.

As a result, the knowledge related to the communication as supporting systems are mapped to the DMM concept: *Communication*. As illustrated in Table 4.8, the knowledge related to humanitarian aid as supporting systems is mapped to the DMM concept: *HumanitarianAid.* The decision-making flowchart for mapping semantic similarity is elaborated in Figure 4.13. The dotted line illustrates the DM knowledge analysis and flow into the ABMs to enable their transfer into the repository. The repository is the representative constructs in the DMM-based repository for each PPRR cycle. If there is only one possible annotated DMM concept in the repository then the mapping process can be undertaken directly. However, if there is more than one possible annotated AB concept in the repository for each of ABMs from the analysis and modelling stage, then a DM expert is required to intervene.

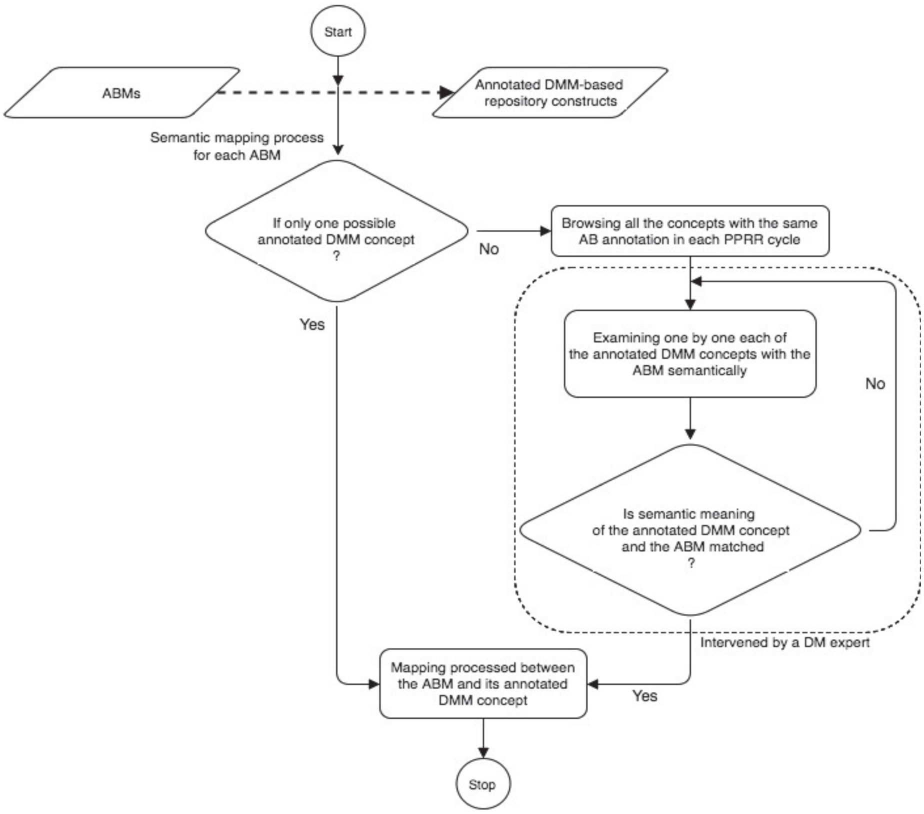


Figure 4.13 Semantic mapping process flow chart.

In this particular case, all the concepts in each of the PPRR phases are automatically classified based on the relevancy of each of the phase, i.e. concepts related to the phase Preparedness are grouped together into that phase. This is as shown in DMM. If there is more than one possible target concept in the repository, only the same annotated concepts in the same phase as ABM would appear. For instance, if the knowledge modelled from the DM document is about the preparedness activities, only the annotated concepts of the Preparedness phase of DMM would come up. This increases the efficiency of mapping process as this automatically reduces the number of iteration the expert needs to revisit.

This task applies iteratively to the rest of the knowledge in the DISPLAN for all the DM phases. The process in Stage 3 is illustrated in a 3D format as presented in Figure 4.14. Finally, in the DMM-based repository the knowledge forms a complete three-dimensional (3D) format. This is illustrated in Figure 4.15. On the X axis, the knowledge is laid down in the PPRR phases while in the Y and Z axis it is represented as the FAML metamodel concepts and the MOF framework respectively. This 3D structure allows the knowledge to be drilled down or rolled up holistically at any point of the timeline of the DM activities representing the DM knowledge from the real world domain to planning/policy to the conceptual levels and vice versa. Eventually, this allows the knowledge to be shared and reused easily for the DM resilience endeavours.

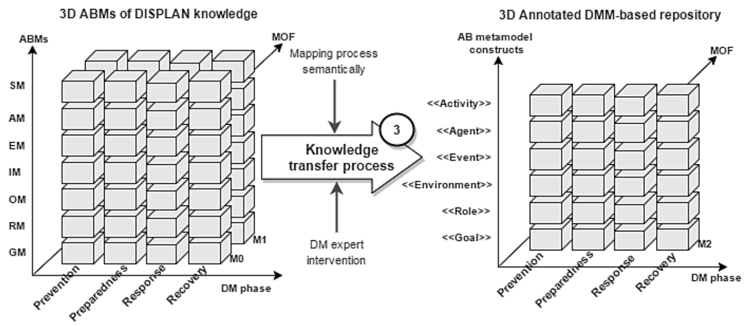


Figure 4.14 Knowledge transfer process in a 3D format.

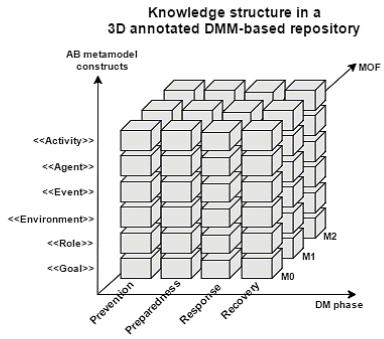


Figure 4.15 A 3D Knowledge structure in annotated DMM-based repository.

4.3 The initial version of knowledge analysis framework

This section presents an initial version of the knowledge analysis framework. This initial version essentially combines the three stages of the framework development described in the previous sections. The complete illustration of the developed knowledge analysis framework is described in Figure 4.16.

In the first stage, the input is the semi-structured DISPLAN knowledge organised in any phase of the DM framework. It then undergoes the AOA processes based on the seven ABMs that are tightly coupled with the MOF framework. The output is the analysed and modelled DISPLAN knowledge arranged in ABMs. This output then serves as an input to be transferred into the repository, the DMM. However, to facilitate the transfer process, the repository should be prepared to allow the depositing process into it. The DMM repository is then annotated and this results in the annotated DMM-based repository. This is described in the second stage. Once the repository is ready for the knowledge transferring, the depositing process is proceeded within the third stage. A DM expert is involved to ensure that the transfer process between each of the ABMs of the DISPLAN knowledge is positioned to its appropriate concept in the repository accordingly. A DM expert measures those two concepts semantically.

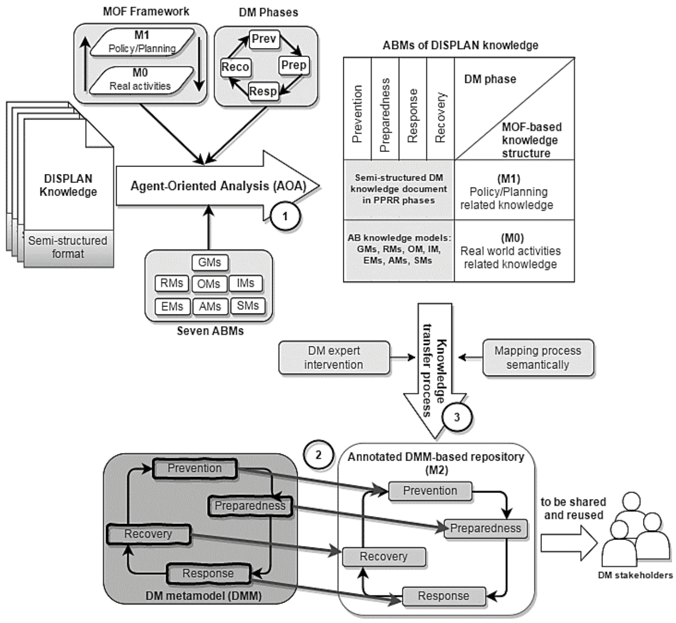


Figure 4.16 The initial version of Knowledge Analysis Framework.

This knowledge analysis framework fundamentally is our research contribution in this thesis. In the DM domain, our developed framework contributes to the DM resilience endeavours to combat the disasters. For the authoritative agencies, for instance, the State Emergency Services (SES) in Australia, Federal Emergency Management Agency (FEMA) in the USA and/or National/Regional Disaster Management Agencies (BNPB/BPBD) in Indonesia, this framework is aimed to convert their complex knowledge structured in the semi-structured DISPLAN in a way that it can be understood comprehensively and holistically. Ultimately, this framework facilitates the sharing and reusing activities. In addition, this framework can be utilized in both types of disaster, natural or man-made.

As can be seen from Figure 4.16, the knowledge in *M0* and *M1* layer will be stacked together with the knowledge concept of *M2* in the annotated DMM-based repository. The way they are structured are based on the MOF framework. While a demarcation is put in each of the PPRR phases based on the urgency in the DM activities, this allows the stakeholders to retrieve the knowledge moving up and down in each phase of the DM time line. Eventually, the stakeholders are able to determine which of the knowledge in the repository is appropriate to respond to the DM activity in each PPRR phase, particularly in helping them in the decision making mechanism. This is detailed in Figure 4.17.

As regards the DSR elaborated in Chapter 3, once an artefact is built, it should be evaluated next. The evaluation is described in the next chapter. This evaluation is conducted by validating the framework with a real case study of flood DISPLAN knowledge from the SES NSW Australia for its efficacy and utility. A DM expert from the SES NSW agency is highly involved in the evaluation process. A tool will be developed to be used in the evaluation process. It is essentially an instantiation of the developed artefact. The aim is to ease the validation process encompassing all the dimensions: functionality, tool, user and domain of the developed artefact. In the next section, the architecture of the tool as an embodiment of the developed framework will be described and discussed.

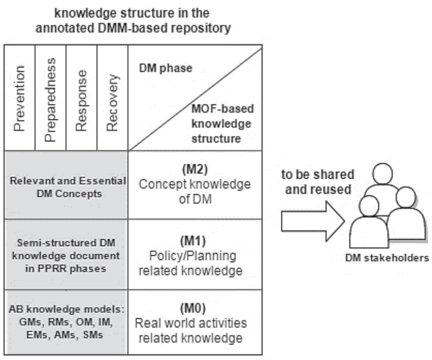


Figure 4.17 A knowledge structure stacked the annotated DMM-based repository.

4.4 Tools to support the developed framework evaluation

As an embodiment of the developed framework, a tool as a prototype is built. In the Design Science Research (DSR) methodology adopted in this research, the tool is called as an instantiation (Gregor & Hevner, 2013; Venable *et al.*, 2016) (This is extensively discussed in Chapter 3). The tool is essentially a manifestation of the artefacts constructed in this research. The aim is to not only show that the framework can be materialised as a concrete application but also to help the developed framework to be evaluated for its all functionalities through the whole artefacts' dimensions. In particular, the tool helps in observing the effectiveness, that is to examine whether the framework works with real case studies, and efficacy, that is to investigate whether the observed artefacts need improvements. The system architecture of the developed framework is drawn in Figure 4.18. As can be seen, the system architecture of the developed framework comprises two block functionalities, namely: (1) AOA tool and (2) disaster knowledge management tool.

The function of the first tool is to analyse and model the seven ABMs. This is fundamentally as elaborated in Section 4.3, the AOA Stage. This tool provides the interfaces by which the knowledge elements of DISPLAN document can be analysed by a knowledge engineer and subsequently arranged them in the corresponding ABMs. In the first tool, the knowledge elements have also represented *M0* (real world knowledge from the DISPLAN) and *M1* (the real word knowledge analysed and modelled) (See Figure 4.18). The output of the analysed and modelled knowledge elements is arranged in an XML (eXtensible Markup Language) file. The XML is employed as in fact it is designed as a format for both human and machine readability. In addition, unlike other formats, for instance HTML, in XML format the content and presentation are structured concurrently. The knowledge elements structured in an XML file is then transformed into the repository, which takes place in the second tool.

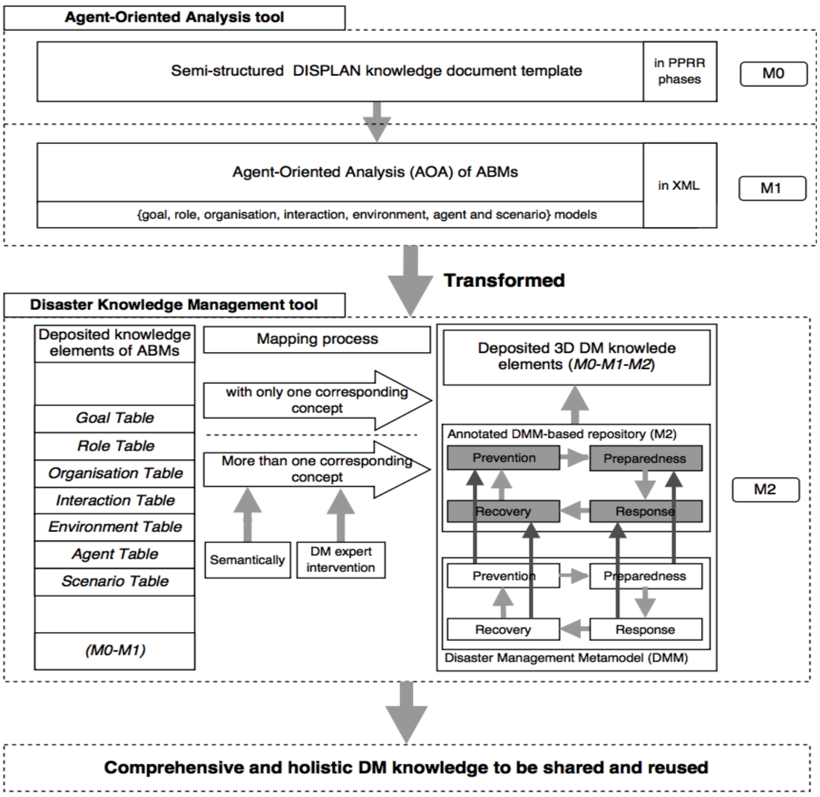


Figure 4.18 System architecture of the developed framework.

In the second tool, the knowledge elements transferred from the first one are deposited into a repository. The repository is developed using a relational database representing elements of all the ABMs from the first tool. As can be seen in Figure 4.18, all the knowledge elements that are analysed and modelled are stored in corresponding tables in the repository representing each of the ABMs. For instance, knowledge elements in *goal model* is stored to goal table, *role model* to role table and so on. In addition, as DMM is utilised as the representation language of the knowledge in the repository, all the concepts and their relationships of the metamodel are also stored in the database. They are stored in the annotated forms for the purpose of their transformations. The annotating DMM process is as discussed in Sub-section 4.2.2. In the MOF framework, the DMM-based repository is positioned as *M2* layer. Once the knowledge elements from the analysis and modelling processes and the annotated DMM-based repository are in the database, the mapping process is commenced. The transfer of knowledge is facilitated by both developed tools and demonstrates the model-to-model transformation. This has been discussed in Sub-section 4.2.3.

We implement these tools by harnessing a web-based technology. A web-server featuring a database server and a server side scripting are set up for this purpose. It employs the Apache® as the webserver platform, MySQL® as the database servers and PHP as the server side script. These applications are utilized not only because they are powerful and widely adopted across the world as a web-based platform standard but also because they are open sources products. This means that the total cost of ownerships of them are the lowest. This technology is also chosen because, once it is placed in a web server, it can be accessed from anywhere within a network, for instance, local, wide, metropolis or internet. In addition, in a web-based environment, the prototype can be turned into a mobile platform with less effort as both these platforms share the same technology environment. Beyond these features, utilizing the web-based environment allows these modelling processes to be distributed to numerous knowledge engineers at the same time. In addition, to ensure that this web-based tool is as light as possible, we also employ Asynchronous Java-script and XML (AJAX) technology for this purpose. The AJAX guarantees that the knowledge modelling can be processed and subsequently accessed without requiring a high specification computer or bandwidth in a network connection. We will show how these tools work with the real case studies in the evaluation stage in the next Chapter.

4.5 Chapter summary

In this chapter, the development of the knowledge analysis framework is presented. This version consists of three stages describing the processes of the framework. The details in each stage describe the process that should be carried out as an integrated process by a knowledge engineer. Generally, these three stages are: 1) Analysis and structuring the knowledge of the DM domain using AB models; 2) Preparing the repository so that it will be consistent with the models resulted from the previous stage; and 3) Transferring the models to the representative repository. These three stages are discussed in Section 4.3 to 4.5. All these three stages are combined together as the complete initial knowledge analysis framework that is presented in Section 4.6.

In this chapter, we presented the seven ABMs: *goal model*, *role model*, *organisation model*, *interaction model*, *environment model*, *agent model* and *scenario model*. These models are adopted from the AOSE paradigm. The justification of adopting AOSE for representing the complex characteristics in the DM domain was elaborated in Chapter 2. As the DM complexities and AOSE paradigm lend themselves to representing each other then it is not surprising that AOSE is suitable for reflecting the DM complex characteristics. The ABMs as the instances then become the manifestations to be used for the representations. For instance, the *goal models* represent the objectives that need to achieve in the DM activities, *role models* describe the responsibilities of each agent and its organisation constraints, *organisation models* define the hierarchy level of the involved entities in the activities, *interaction models* manage to what extent those entities are interacted, *environment models* represent that agents are situated in an environment, *agent models* represent the autonomous characteristics of agents in which they are framed in a time-sensitivity constraint and *scenario models* bind all those characteristics together representing proactiveness and reactiveness of agents with pre- and post-conditions.

To the best of the author's knowledge, although ABM has long been recognized as the most representative tool for analysing complex domains, this thesis is the first to justify that ABMs are capable of analysis and extracting the complex characteristics of the DM domain knowledge. In particular, ABM is employed as a descriptive mode in requirement analysis stage. This later is structured for a further development phase in the area of a better and more comprehensive DM knowledge management and DM decision support system. In the DM activities, these are extremely beneficial for the development of resilience endeavours as they allow stakeholders to be able to identify the most appropriate of any of its activity at any point of the DM time line. For the repository, the DMM adopted in this thesis guides the stakeholders to have a broader understanding to the essential and relevant concepts for the decision making mechanisms. In addition, the MOF facilitates the knowledge being identified in the decision making to planning/policy to real world activities levels. With respect to the MOF hierarchy, not all AB models are represented equally. Some models generate more constructs at the *M0* level than others. Other models generate more constructs at the *M1* level. For instance, the *agent model* and *scenario model* generate more constructs at *M0* whilst *goal model* and *role model* generate more constructs at *M1* level.

As in the DSR research, once the artefact is built, the evaluation process should be undertaken. In Chapter 5, the first validation of the artefact is carried out. This is conducted by validating the developed artefact with a real case study of the Disaster Management Plan (DISPLAN) knowledge of the State Emergency Service New South Wales (SES NSW). Toward this evaluation, a system prototype of the framework is also developed. This aims to help the evaluation process to be conducted.

5 The 1st framework evaluation: *Wagga-Wagga Case Study*

In this chapter, the framework developed in Chapter 4 is evaluated. This is the first of three evaluations to be performed in this thesis. As described in the DSR methodology in Chapter 3, evaluating the artefact (the framework in this thesis) should encompass all the dimensions of the developed artefact to guarantee its efficacy and effectiveness. In this research, the first evaluation scrutinizes the framework by validating it with a real case study; that is a Wagga-Wagga (WW) DISPLAN knowledge of the SES NSW Australia. The SES NSW is the authoritative agency that is responsible for the management of flood disasters. In conducting this research, the DM experts from the SES agencies collaborate closely with the author for investigating the case study evaluations. In particular, the DM expert is involved in advising of the real problems of the DM activities from the practitioner's perspective to evaluate the case studies obtained from the agencies towards evaluating the developed framework.

The involvement of the experts is also with the purpose of ensuring that the framework works as intended to address the identified problems. The experts' involvement will begin in Chapter 6. In addition, a tool to help the evaluation process is developed to operationalise the framework and the reuse of the converted knowledge. Eventually, the framework will be validated thoroughly using knowledge from the case study from the analysis and modelling stage up to the transferring process into the DMM-based repository. In Section 5.1, the disaster type is justified in this evaluation strategy along with the reason for taking the case study from WW NSW Australia. In Section 5.2, the framework is illustrated in the Wagga-Wagga case study. As the framework is illustrated, a tool developed to support the analysis and the transfer of knowledge into the repository is also illustrated. Section 5.3 shows the repository and how it can be accessed to retrieve knowledge. In Section 5.4, the results of the case study are discussed and its implications to improvements in the framework are identified. Section 5.5 summarises the chapter and foreshadows the improvements to be detailed and evaluated in Chapter 6.

5.1 Wagga-Wagga flood DISPLAN knowledge

As early as the first European settlements began on the Hawkesbury River in Sydney, development pressure in flood risk areas has exposed people and communities to flooding and resulted in deaths and high damage costs. Flood deaths rank second behind heatwaves for natural hazard fatalities in Australia (Gissing *et al.*, 2010) and the cost of disasters generally is increasing by tens of millions of dollars per year. Climate change modelling suggests that while there are likely to be little changes in average rainfall across the state by 2030, there will be large seasonal differences. The frequency of coastal flooding may increase as a consequence of sea level rise and potential increased frequency of storm surge events, particularly as the events coincide. Risks to population and infrastructure are likely to increase as a consequence of sea level rise and the increased severity and frequency of storms and coastal flooding (NSW Government, 2013). In addition, flood is the most pervasive disaster in the world (Paul & Routray, 2010).

Amidst this backdrop of rarer but more severe weather events is the reality that overall exposure of people and infrastructure is increasing from ongoing development and population increase. Disaster risk is going up, not down, and risk management is about minimisation, not overall net reduction. Also, even while future disasters may be generally rarer leading to decreased awareness, already communities have little contemporary knowledge of disasters, especially large disasters which have occurred in the past but just outside the current life of those alive today. Thus, a central concern for communities and all levels of government is how to ensure that we have learnt from past experience and have planned for the future to create more flood resilient communities.

The regional town of Wagga-Wagga (WW) and surrounding rural area, in the City of WW Local Government Area, NSW, is situated on the Murrumbidgee River floodplain, the second longest river in Australia. The history of Flooding in WW is a good example of the sporadic frequency of flooding in inland Australia being the driest inhabited continent on Earth. The sporadic nature presents major challenges for maintaining community and Government awareness and knowledge of flooding and of ongoing flood resilience with large periods of drought between major floods.

Flood disaster management in New South Wales (NSW) is coordinated through a set of documented emergency/disaster plans and arrangements at the Local, Regional and State levels. The WW Local Flood Plan (LFP) is a flood hazard specific sub-plan supporting a Regional Disaster Management Plan (DISPLAN). Other sub-plans focusing on Health, Agriculture and Energy and Utilities etc., also support the Regional DISPLAN and are enacted during disasters such as floods. The Regional DISPLAN is in turn a sub-plan supporting the State Emergency Management Plan (EMPLAN).

The WW DISPLAN is maintained to prepare for, manage the response to and support recovery from flood disasters. It is maintained by the SES NSW in conjunction with the WW City

Local Government and their representative Local Emergency Management Committees comprised of local stakeholders. The plan can be downloaded freely from the SES website[3]. In the context of this research, the LFP is considered as a semi-structured document, as the knowledge in it has been populated and written in a particular style and structured by practitioners involved in the DM for floods. It covers knowledge in three phases: Preparedness, Response and Recovery representing. However, in this research the Preparedness and Response phases will only be presented as they both have represented pre- and post-disaster phases of DM. In fact, this evaluation mostly occurs in Response phase as it contains more elements than other phases. This evaluation has been exhibited partly in here (Inan *et al.*, 2015).

5.2 Applying the framework in Wagga-Wagga DISPLAN

What follows in this section, is the evaluation activity of the developed framework as described in Chapter 4. It comprises three stages: (1) Analysis and modelling DM knowledge based on AOA; (2) Annotating concepts of DM metamodel; and (3) Transferring the ABMs into the annotated DMM-based repository.

5.2.1 Stage 1: Wagga-Wagga knowledge modelling based on AOA

In the first stage, analysis processes are applied to the semi-structured knowledge of DISPLAN using the seven ABM templates described in Chapter 4, the framework development. In this stage, knowledge of DM phases from WW DISPLAN document is reformulated using the AOA. This is a manual labour intensive activity and produces a long trail of documents (included as Appendix C in this thesis). This process is performed iteratively to ensure that all knowledge in the DISPLAN has been appropriately captured. The process begins by producing the *goal models*. These represent the purposes intended out of activities in a DISPLAN. This model also identifies role(s) played by agent(s) involved in the activity to pursue the goal. Once the goal models are considered mature, processing one of these model templates can follow: the *role model*, the *organisational model*, or the *interaction model*. However, the *environment models* can only be completed once the *role models* are completed. Likewise, the *agent model* and *scenario model* can only be processed once the *environment models* are completed as the environment knowledge elements in both models are gathered from the *environment models*.

Some additional iterations might be required to make sure that all the knowledge has been analysed and all connections between the seven models have been made and identified. For instance, a knowledge element of actions in an *agent model* needs to refer to corresponding

[3] http://www.floodsafe.com.au/

activities in the *scenario model*, which in turn should have corresponding sub-goals in a *goal model*. Another example is identifying responsibilities in a *role model*. Responsibilities should also be identified in a *goal model*. Thus, iterations over an evolving set of models are required. With each iteration, the newly identified knowledge may require the modeller to revisit earlier versions of, for example, the *goal models* or *role models*. The ABMs generally are closely-related models (Winikoff & Padgham, 2013). Some ABMs share the same elements. In other words, some elements in some ABMs represent the same knowledge so those particular elements can be exchanged directly. This reduces the analysis and modelling effort. The relations between iteration and ABMs are drawn in Figure 5.1. The analysis and modelling of each of the ABMs of the WW flood DISPLAN knowledge is illustrated in the remainder of this section. The illustration is focussed on developing all the models of a critical goal, *Arranging Flood Intelligence Source* (The case study itself contains many goals- as shown in Appendix C. What is shown here is about 10% of the case study).

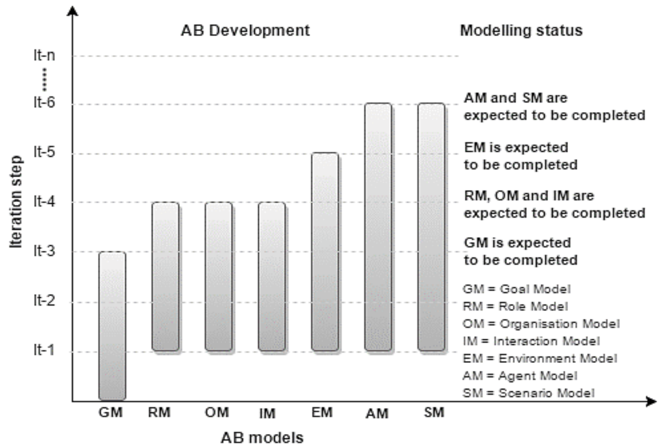


Figure 5.1 Relations between iteration and ABMs in the AOA stage.

5.2.1.1 The goal model

For goal modelling, all the main goals and the sub-goals for each of the main goals are identified. In addition, the role(s) that is/are responsible for each of the goals is/are also identified. The *goal model* of WW flood DISPLAN knowledge for only one particular main goal is drawn in Figure 5.2. A main goal identified from the WW DISPLAN knowledge document is "*arranging flood intelligent sources*" and the initiator of it is WW SESLOC (WW SES Local Operational Controller). It is one among many and various main goals identified from the Response phase of the WW DISPLAN. A knowledge engineer goes through the DISPLAN vertically or horizontally to identify the goals. In other words, the knowledge engineer continues to examine the DISPLAN knowledge by either identifying all the main goals and laying them out horizontally in one layer first or by completing all the sub-goals for that particular main goal in a tree-like structure to the end. In this evaluation, both these approaches are feasible and adopted in a mix or interleave fashion. This implies that the knowledge engineer might change the approach from horizontal or vertical whenever necessary until all the goals and roles for the *goal models* are fully modelled.

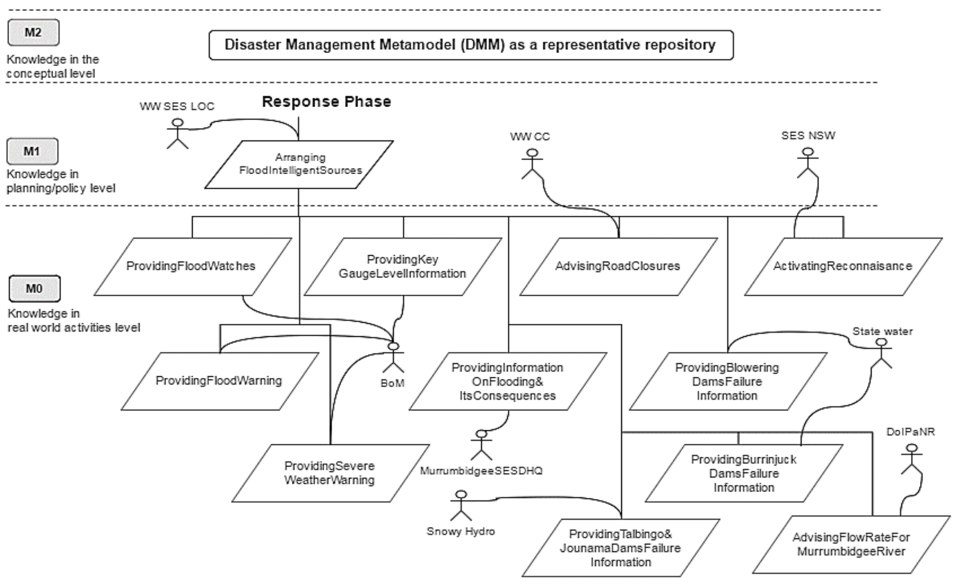


Figure 5.2 A *goal model* of WW DISPLAN knowledge, as an example.

In Figure 5.2, only one of main goals is shown. All its sub-goals and the roles that are responsible for each of these sub goals are also shown. A knowledge engineer then goes through the DISPLAN to identify all other goals (main goal and the sub-goals) and their roles subsequently structure them in other *goal models*. Once they are in place, a knowledge engineer then assigns the main goal as *M1* and all its sub-goals as *M0*. This demarcation is based on the knowledge they represent. In other words, based on MOF, the main goals represent the knowledge in the planning/policy level while for people on the ground they need a more directly executable knowledge. As such, all the sub-goals for each of those main goals are structured as *M0*. This process is undertaken iteratively until all the goal knowledge elements of the document and the marking process based on MOF are completely analysed and modelled in the *goal models*. The knowledge engineer can always intervene in any particular *goal model* analysed and modelled previously whenever necessary to improve its knowledge elements.

5.2.1.2 The role model

As per Figure 5.1, any of the *role model* or *organisation model* or *interaction model* can be processed after the goal model. However, in this research, the *role model* is processed next after the *goal model*. A *role model* essentially defines the responsibilities and the constraints of that role that has been identified in the *goal model*. The knowledge elements of the *role model* are similar to the *goal model* although each of the two models represents different contexts. Therefore, instead of revisiting the DISPLAN knowledge document, the knowledge engineer can observe the *goal model* only to complete the *role model*. A *role model* of the WW DISPLAN is shown in Table 5.1. The table shows one role, namely BoM (Bureau of Meteorology) analysed from the Response phase of the document. The responsibility element in the model describes all the sub-goals for which BoM is responsible for. To complete all the responsibilities in the model, a knowledge engineer then revisits the *goal model* to get all the knowledge elements which the BoM is associated with and structure them in a responsibility element of the *role model*. As for the constraint elements, a knowledge engineer should revisit the original DISPLAN of the Response phase to analyse and lay them down in the *role model*. In this example, there are no knowledge constraints subjected to the role of BoM (Bureau of Meteorology).

Table 5.1 The *role model* of WW DISPLAN knowledge, an example.

DMM-based repository		**M2**
Role knowledge		**MOF layer**
Role ID	R4	M1
Role Name	BoM	
Description	The responsibilities of the BoM playing the role in a flood disaster event of a Response phase.	
Responsibility	1. Providing flood watches 2. Providing flood warning 3. Providing severe weather warning for flash flooding 4. Providing key gauge level information	M0
Constraint	-	

Once the knowledge elements of the role of the BoM is completely analysed and modelled, the knowledge engineer designates which knowledge belongs to either *M0* or *M1*. These activities are conducted iteratively. As *M1* is aimed for knowledge in the planning/policy layer, thus the elements: role ID, role name and description represent it whereas the elements: responsibility and constraint are assigned as *M0*. The knowledge in these both layers eventually will be mapped to the appropriate DMM concept in the repository.

5.2.1.3 The organisation model

The *organisation model* is based on an analysis of the hierarchy levels of the roles played by agents. In Figure 5.3 it only shows an *organisation model* where all the roles are identified from the *goal model* in Figure 5.2. The *organisation model* is aimed to equip all the entities involved in the DM activities with the knowledge of whom and how to contact other authoritative entities whenever necessary. Towards completing the *organisation model*, all the entities are identified from the *goal model*. However, for their relationships, a knowledge engineer needs to revisit the DISPLAN to be able to identify them. In addition, the common sense knowledge can also be used by a knowledge engineer to map the relationships between the entities. If there are similar organisations and in the different hierarchy structures then this informs that one controls or is controlled by another, for instance, the organisation of the SES in the state and municipality levels. The one in the state controls the one in regional or municipality level. Likewise, if the organisations are different but they are aimed for the state level or for the municipality level only, then they are peers. As can be seen from Figure 5.3, the SES NSW *Controls* Murrumbidgee SES Division Headquarter (DHQ) (or Murrumbidgee SESDHQ *isControlledB*y the SES NSW). Similarly, the Murrumbidgee SESDHQ *Controls* the WW SES LOC (or otherwise). On the other hand, WW SES LOC *isPeer* with the WW City Council (WW CC) as they both lead organisations in the city level. This relationship applies the same for the hierarchy level between the SES NSW and Snowy Hydro or State Water or BoM or the Department of Infrastructure Planning and Natural Resources (DoIPaNR) (See Figure 5.3).

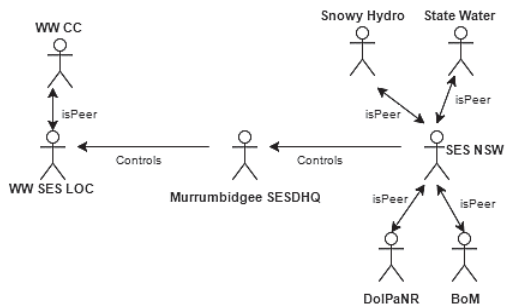


Figure 5.3 An *organisation model* of WW DISPLAN knowledge, as an example.

Once the knowledge elements of *organisation models* are completely analysed and modelled, a knowledge engineer then marks which knowledge element in the model is structured as either *M0* or *M1*. This illustration is drawn in *Table 5.2*.

Table 5.2 The *role model* of WW DISPLAN knowledge structured in table

DMM-based repository					**M2**
Organisation knowledge					**MOF layer**
Role A		Organisation knowledge	Role B		M1
Role Name	<SESLN> SESLOC	*isControlledBy*	Role Name	<SESLN> SESLHQ	
Description	<SESLN> State Emergency Service Local Operational Controller		Description	<SESLN> State Emergency Service Local Headquarter	M0
Role Name	<SESLN> SESLHQ	*isControlledBy*	Role Name	<SESReg> SESRHQ	M1
Description	<SESLN> State Emergency Service Local Headquarter		Description	<SESReg> State Emergency Service Regional Headquarter	M0
…and so on					

As can be seen, all the role name elements are structured as *M1* as they inform only the name of the role and the descriptions are assigned as *M0* as they detail the role name elements. The knowledge engineer can always revisit this model to improve the knowledge elements in it.

5.2.1.4 The interaction model

The interaction model is aimed to model to what extent the roles interact with each other. While in the *organisation model*, the knowledge regarding whom and how to contact are provided, in the *interaction model*, for what purposes an entity contacts other entities are analysed and structured. This implies that in the case of contacting other entities in a disaster event, an entity needs to equip itself with a clear understanding of which other entities need to contacted, communicated with, and to what extent. This *interaction model* is illustrated in Figure 5.4.

For each sub-goal in the *goal model*, whenever there is more than one role responsible for it, then that particular sub-goal relates those roles. The roles are identified and included in the *interaction model*. I.e. only those sub-goals where more than one role is involved are used in the analysis. As illustrated in Figure 5.4, the role WW SES LOC is the centre of the interaction between those roles. This is because that role serves as the initiator that is responsible to accomplish the main goal. Therefore, that role interacts with all other roles if they are participating in the same sub-goals.

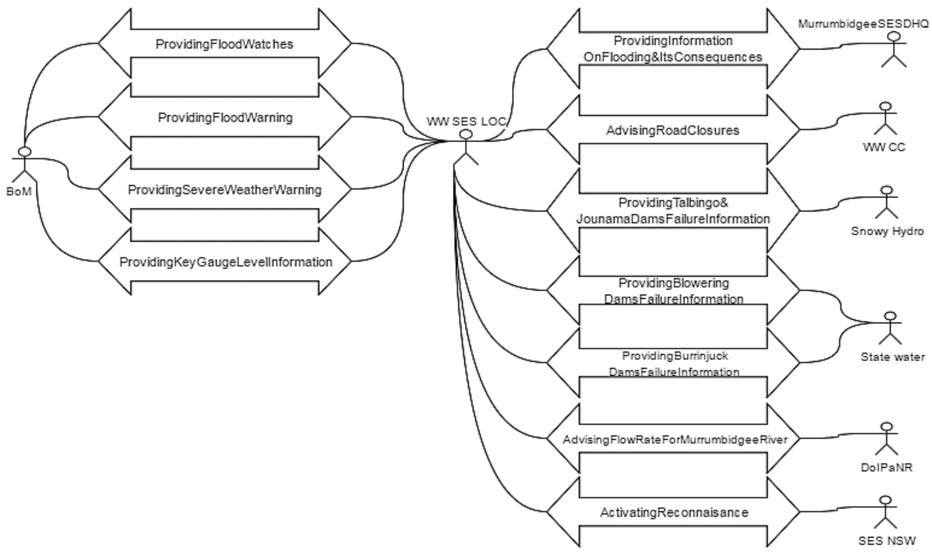


Figure 5.4 An *interaction model* of WWDISPLAN knowledge, as an example.

Once all the *interaction models* are in place, the knowledge engineer assigns each of the knowledge elements in this model as either *M0* or *M1*. This is shown in Table 5.3. As illustrated, the element *rolePursueGoal* is added to describe the activity to which both roles are interacted for. With respect to MOF, the role name and the element *rolePursueGoal* that define a brief activity are marked as *M1* as these elements represent the knowledge for policy/planning level, whereas the more complete descriptions of the roles and the activities are assigned as *M0* as they inform the knowledge to be consumed for people on the ground. As these analysis and modelling activities are performed iteratively, the knowledge engineer can always go back to improve the knowledge in the model.

Table 5.3 An *interaction model* of WW DISPLAN knowledge structured in table form.

DMM-based repository			**M2**
Interaction knowledge			**MOF layer**
Role A	*rolePursueGoal*	Role B	M1
WWSESLOC	*Providing flood watches*	*BoM*	
Wagga-Wagga State Emergency Service Local Operational Controller	Providing flood watches which give an early appreciation of developing meteorological situations that could lead to flooding.	Bureau of Meteorology	M0
	Flood Warnings, which include river height readings and height-time predictions.		
WWSESLOC	*Providing information of flooding and its consequences*	*Murrumbidgee SESDHQ*	M1
Wagga-Wagga State Emergency Service Local Operational Controller	Providing information of flooding and its consequences including those in nearby council areas.	Murrumbidgee State Emergency Service Division Head Quarter	M0
…and so on			

5.2.1.5 The environment model

The *environment model* captures knowledge elements that describe the situatedness of an agent in an environment. Related environmental elements are identified and these serve as resources required by an agent to pursue the DM activities. In this evaluation stage, the knowledge engineer needs to revisit the DISPLAN to be able to analyse and identify all the related environment knowledge elements and structure them in the *environment models*. As with the process in other models, this is also performed iteratively. An example of the *environment model* is depicted in Table 5.4. As shown, the environment knowledge that is shown is the "List of areas to be monitored in the active reconnaissance". This element is identified from the Response phase of the DISPLAN. The knowledge element informs the list of the areas that needs to be monitored by the SES NSW in a Response phase. Subsequent elements detail that knowledge, for instance, the location names and addresses. In addition, the role(s) that utilizes this environment knowledge element is also modelled and structured in this model.

The knowledge engineer next marks each of the knowledge elements as either *M0* or *M1*. With respect to MOF framework, the elements entity ID, name and description of the environment are assigned as *M0* as these are the typical knowledge elements in the planning/policy level, whereas the other elements that describe the details of the element are marked as *M0*. Moreover, as for new role element details, a knowledge engineer can revisit the *role*. In this example, the role identified from the role model is the SES NSW.

Table 5.4 An *environment model* of WW DISPLAN knowledge, an example.

DMM-based repository			**M2**
Environment knowledge			**MOF layer**
Environment Entity ID	E16		M1
Environment Name	List of areas to be monitored in the active reconnaissance		
Description	List of areas of the WW municipality to be monitored to provide the flood intelligence sources during times of flooding.		
Attributes	#	Unique number distinguishing the data	M0
	Location name	Flowerdale flats, main town levee, eastern section of the Sturt Highway, WW beach caravan park, North wagga levee, Gumly-Gumly levee, Urangquinty leeve, Tarcutta levee.	
	Address	The addresses/geo locations for each of them	
Roles Involved	R12 (SES NSW)		

5.2.1.6 The agent model

The *agent model* essentially informs a set of scenario activities to achieve each of the main goals but for only one particular agent. In this evaluation, the foundation of analysis and modelling the *agent model* is based on *goal model* and *environment model*. While the knowledge elements of action in the *agent model* are obtained from the *goal model*, the environment knowledge is gathered from the *environment model*. Nonetheless, as for the knowledge element of triggers, the knowledge engineer should revisit the DISPLAN to be able to portray these characteristics. These basically define the activities in a time dimension. They serve to notify an agent the time at which actions should be performed in responding to the situation to achieve the designated main goal.

In Table 5.5 the *agent model* is illustrated for one particular agent, namely *organisation type* agent that plays a role as a BoM. As can be seen, while the activity element in the table essentially constitutes a scenario comprising the element *activity name*, *trigger* and *action*, the *functionality* element is the objective to be achieved, namely: "*arranging flood intelligent sources*". In addition, in the trigger, anytime any of the conditions is met the activities will be performed as defined in the element *actions*.

In this example the role played by the agent is the *R4.* A knowledge engineer can just refer back to the *role models* with this reference if required. The last knowledge element in this model is the environment entity. It is referred to as *E12,* therefore to be able to get the detail of the knowledge, a knowledge engineer refers to the same ID in the *environment model* to get it.

Finally, the knowledge engineer determines assignment of the knowledge elements in the *agent model* to either *M0* or *M1*. In the *agent model*, while knowledge elements: *agent type id, name, description* and *reference* are marked as *M1* as these elements are essentially for the consumption in the policy/planning level, the element activity and environment are assigned as *M0* as basically they are the knowledge details that guide the agent to perform the activities. The *M0* knowledge is the typical one for the people on the front line in the DM activities.

Table 5.5 An *agent model* of WW DISPLAN knowledge, as an example.

<table>
<tr><th colspan="3">DMM-based repository</th><th>M2</th></tr>
<tr><th colspan="3">Agent knowledge</th><th>MOF layer</th></tr>
<tr><td>Agent type ID</td><td colspan="2">Organisation type</td><td rowspan="4">M1</td></tr>
<tr><td>Agent name</td><td colspan="2">Name BoM</td></tr>
<tr><td>Description</td><td colspan="2">The agent plays role as Bureau of Meteorology (BoM)</td></tr>
<tr><td>Reference</td><td colspan="2">R4 (BoM)</td></tr>
<tr><td rowspan="4">Activity</td><td>Activity name:</td><td>BoM arranges the flood intelligent sources</td><td rowspan="5">M0</td></tr>
<tr><td>Functionality:</td><td>Arranging flood intelligent sources</td></tr>
<tr><td>Trigger:</td><td>▪ On the receipt of a Bureau of Meteorology Preliminary Flood Warning, Flood Warning, Flood Watch, Severe Thunderstorm Warning or a Severe Weather Warning for flash flooding.
▪ On the receipt of a dam failure alert.
▪ When other evidences leads to an expectation of flooding within the council area.</td></tr>
<tr><td>Action:</td><td>1. Providing flood watches
2. Providing flood warning
3. Providing severe weather warning for flash flooding
4. Providing key gauge level information</td></tr>
<tr><td>Environment Entity</td><td colspan="2">E12</td></tr>
</table>

5.2.1.7 The scenario model

The *scenario model* binds all the knowledge elements of the previous six ABMs. In particular, the knowledge is structured in a way that allows the stakeholders to create a story telling of the decision making process in DM resilience endeavours comprehensively and holistically. An example of a *scenario model* is illustrated in Table 5.6. This is one of the *scenario models* analysed and modelled from the DISPLAN. This model is drawn from the objective, "*arranging flood intelligent sources*". This objective is basically obtained from the *goal model* in Figure 5.2. The role responsible for this objective is the *R1* (WW SES LOC) which, therefore in the *scenario model* is modelled as the initiator of it. To be able to see the detail of this initiator, a knowledge engineer can just observe from the *role models* with the same identity. The knowledge element of trigger in the *scenario model* is acquired from the *agent model* where they both have the same objective. While pre-condition is the condition describing the activities just before performing the activities in *scenario model*, the post-condition describes the condition once the activities in the *scenario model* are completed.

Table 5.6 A *scenario model* of WW DISPLAN knowledge, an example.

DMM-based repository					**M2**
Scenario knowledge					**MOF layer**
Scenario	S6				M1
Name	Arranging flood intelligent sources				
Goal	Arranging flood intelligent sources				
Initiator	WWSESLOC (R1)				
Trigger	▪ On the receipt of a Bureau of Meteorology Preliminary Flood Warning, Flood Warning, Flood Watch, Severe Thunderstorm Warning or a Severe Weather Warning for flash flooding. ▪ On the receipt of a dam failure alert. ▪ When other evidence leads to an expectation of flooding within the council area.				M0
Pre-condition	1. The response operation has been begun 2. The BoM has been contacted to develop the flood warning through Murrumbidgee SESDHQ 3. These following persons and organisations have been contacted regardless the locations and severity of the flood: (1) WWCC Local Emergency Operations Controller, (2) WWSES Unit, Murrumbidgee SESDHQ, (3) WWCC Local Emergency Management Officer, (4) WWCC Mayor				
Post-condition	Flood intelligent sources are already arranged				
Description	-				
Condition	***Step***	***Activity***	***Role***	***Env. Entity***	
Interleave	1	Providing flood watches	R4	E5	
	2	Providing flood warning	R4	E6	
	3	Providing severe weather warning for flash flooding	R4	E7	
	4	Providing key gauge level information	R4	E8	
	5	Providing information of flooding and its consequences	R3	E9,E10	
	6	Advising road closures	R6	E13	
	7	Providing Talbingo and Jounama Dams failure information	R12	-	
	8	Providing Blowering Dam failure information	R13	-	
	9	Providing Burrinjuck Dam failure information	R14	-	
	10	Advising flow rate for Murrumbidgee river	R19	E14	
	11	Activating reconnaissance	R2	E16	

The activities of the *scenario model* themselves are defined in the element *activity*. Each of the activities is equipped by the knowledge element of role(s), that describes the one(s) that is/are responsible for each of the activities, and the environment knowledge that defines the resource(s) required in that particular activity and used by role(s). For instance, an example of this is a sub-activity "*providing information of flooding and its consequences*". This activity requires environment knowledge of *E9* and *E10* and involves role of *R3* to accomplish it. In addition, the element knowledge of condition describes whether the scenario activities are performed parallel or interleaved or sequential. This implies that this element only has an effect if the activities are performed in a sequential fashion where the step of those activities determines how effectivity the objective is accomplished.

As in other previous models, a knowledge engineer then assigns each of the knowledge elements in the *scenario model* as either *M0* or *M1*. In the *scenario model*, while knowledge elements: *scenario name, goal* and *initiator* are marked as *M1* as these elements are essentially for consumption in the policy/planning level, the rest of the elements are assigned as *M0* as basically they are the knowledge details activities involving entities and the resources to be performed.

It is worth noting that the knowledge elements in *scenario model* and *agent model* are the same but knowledge elements of pre- and post-condition. They both summarize the activities to facilitate the easiness of decision making mechanism. The stakeholders can simply create a story telling in performing a DM activity from the knowledge in both the models' structures comprehensively and holistically. However, in *agent model*, the emphasis of the activities is specified for only one particular agent. In other words, all the activities described in one particular *agent model* are intended only for the agent that plays a particular role to accomplish the main goal, whereas, in *scenario model*, the focus is on the objectiveness harnessing all the identifiable elements. As such, all the knowledge elements are put together in a way so that they are tightly coupled and synchronized to achieve that objective.

5.2.2 Illustrating the Agent Oriented Analysis (AOA) using the developed tool

This section illustrates the process in the AOA Stage utilising the tool constructed for this purpose. As explained in Section 4.7 in the previous Chapter, this is the AOA tool. The interface of the AOA tools is shown in Figure 5.5. The interface facilitates all the analysis activities that occur in previous Section 5.2. A knowledge engineer is able to select and switch between the various ABMs as necessary. At first, the knowledge in the WW DISPLAN is analysed for each of the ABMs and modelled in the corresponding knowledge elements in each model ranging from the *goal model, role model, organisation model or interaction model, environment model, agent model* and *scenario model*. This interface structures the output of the analysis (i.e. the models) in an XML format. A single XML file representing all the knowledge elements of all ABMs can be generated from the tool. The structure of the XML is shown in Figure 5.6. In the figure, the knowledge elements of Response phase analysed and modelled of the WW flood DISPAN are shown in XML format.

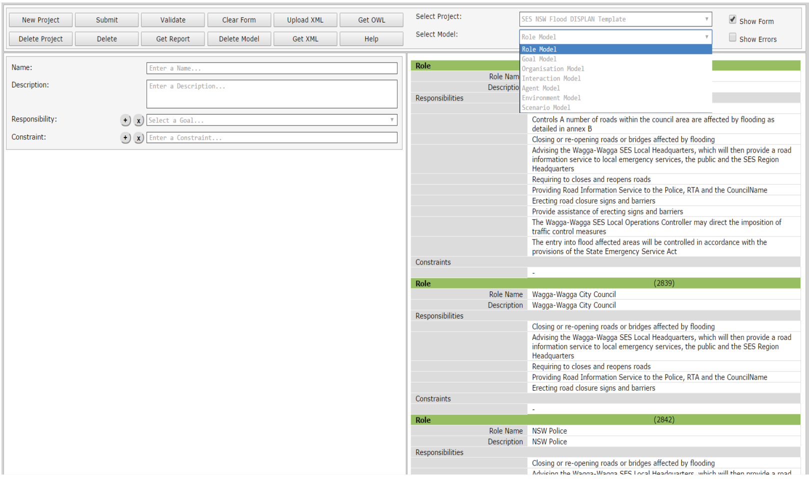


Figure 5.5 The web-based interface for modelling the seven ABMs.

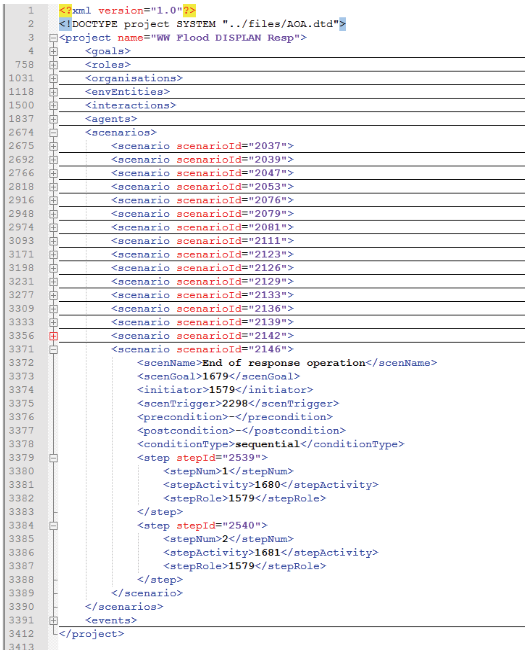


Figure 5.6 The analysed and modelled DM knowledge in XML structure.

All knowledge elements of the seven ABMs are organised in one single XML file to be effectively maintained in the transfer process. As can be seen, each of the elements of each ABMs is represented using a unique ID element. Each ID refers to an element representing the particular knowledge that later can be used in other model efficiently. Once all the knowledge elements from the DISPLAN are fully converted, the next stage is transferring them into the repository. However, to allow this to happen, the DMM-based repository needs to be prepared. This is shown next. This is with the aim of preparing the repository for the transferring process.

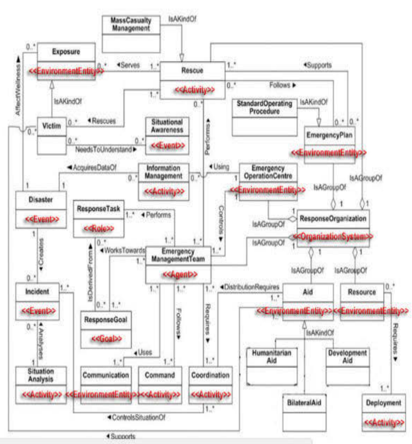
5.2.3 *Stage 2: Annotated DMM*

In this stage, the concepts of the DMM are annotated with the corresponding ones of the FAML metamodel. The developed tool described in Chapter 4 (and detailed in Appendix A) is used to illustrate the annotating process in this stage. This prepares DMM for the transfer process. In Chapter 4, the detailed processes of the annotating process for Preparedness and Response phases was shown. The DMM concepts remain unchanged. The concepts related to goals, that need to be achieved, are annotated with the construct <<*goal*>> of the FAML metamodel, the concepts of agent are annotated with the construct <<*agent*>>*,* the concepts of task representing the responsibilities are tagged with <<*role*>>, the related activity concepts are tagged with <<*activity*>> and the related environment concepts are tagged with <<*environmentEntity*>>.

The right side of Figure 5.7 shows the annotated DMM-based concept for the Response phase, and the DMM concepts with each of their corresponding FAML metamodel one are on the right. For instance, as for the concepts: *Aid*, *BilateralAid* and *HumanitarianAid* are the DMM concept representing the environment knowledge in the DM activity, therefore they are annotated with the FAML metamodel concept it represents, namely <<*EnvironmentEntity*>>. Likewise, the DMM concepts *Coordination* and *Deployment* are tagged with the FAML metamodel concept <<*Activity*>> as they both essentially represent the activities to be undertaken in the DM. Therefore, they are both tagged with the corresponding FAML metamodel concept representing the activity as well, namely <<*Activity*>>. Nevertheless, although this is a one-off process, a DM knowledge engineer can always revisit to improve this whenever necessary.

Home | mGoal | mRole | mOrganisation | mInteraction | mEnvironment | mAgent | mScenario | **Response** | Project | How To | About |

M2: Disaster Management (DM) Metamodel - Concepts and Relations



Annotated DMM concepts of **Response Phase**

#	DMM Concept	Annotated Concept	#	DMM Concept	Annotated Concept
1	Aid	<<Activity>>	14	Incident	<<Event>>
2	BilateralAid	<<EnvironmentEntity>>	15	InformationManagement	<<Activity>>
3	Command	<<Activity>>	16	MassCasualtyManagement	<<Activity>>
4	Communication	<<EnvironmentEntity>>	17	Rescue	<<Activity>>
5	Coordination	<<Activity>>	18	Resource	<<EnvironmentEntity>>
6	Deployment	<<Activity>>	19	ResponseGoal	<<Goal>>
7	DevelopmentAid	<<EnvironmentEntity>>	20	ResponseOrganization	CentralConcept
8	Disaster	<<Event>>	21	ResponseTask	<<Role>>
9	EmergencyManagementTeam	<<Agent>>	22	SituationalAwareness	<<Event>>
10	EmergencyOperationCentre	<<EnvironmentEntity>>	23	SituationAnalysis	<<Activity>>
11	EmergencyPlan	<<EnvironmentEntity>>	24	StandardOperatingProcedure	<<EnvironmentEntity>>
12	Exposure	<<EnvironmentEntity>>	25	Victim	<<EnvironmentEntity>>
13	HumanitarianAid	<<EnvironmentEntity>>			

Figure 5.7 A web-based annotated DMM-based structure for the Response-phase.

The annotated DMM-based repository also shows the domain relations and other concepts where a particular concept relates to or related from (A relation goes both sides). This is illustrated in Figure 5.8. For instance a DMM concept *EmergencyManagementTeam* is annotated with FAML metamodel concept <<*agent*>>. The other eight (8) concepts and their annotations related directly to that particular concept are *Coordination <<Activity>>*, *Command <<Activity>>*, *Communication <EnvironmentEntity>>*, and so forth (See Figure 5.8). The domain relations connect *EmergencyManagementTeam* to those other concepts to be able to be understood effectively by the stakeholders. In this context, a representative relation is put in between the related concepts. It means the *EmergencyManagementTeam <<agent>>* *Involves* *Coordination* and *Command* as *<<Activity>>*, *Uses* *Communication* and *EmergencyOperationCentre* as *<<EnvironmentEntity>>*, to *Pursues* *ResponseGoal* as *<<Goal>>* and *Plays* *ResponseTask* as *<<Role>>*. This understanding applies to both sides and to other relations. For instance, as can be seen from Figure 5.8, R*esponseTask* is related directly to two concepts: *EmergencyManagementTeam* and *ResponseGoal*. This informs that *ResponseTask* as *<<Role>>* *is Played by* *EmergencyManagementTeam* as *<<Agent >>* to *Pursues* *ReponseGoal* as *<<Goal>>*.

The way the concepts are structured and how they are related essentially is the foundation of a comprehensive and holistic decision making mechanism. This is because once a concept is identified the other relevant and essential concepts are also identified which in turn will help the stakeholder to identify the relevant knowledge completely. These annotations configure the repository to be used to facilitate the transferring process. The next stage is transferring the DM knowledge extracted in Stage 1 to this annotated DMM-based repository. This is elaborated on in Stage 3.

Concept and the annotation	
DM Phase	**Response**
Concept	**EmergencyManagementTeam**
Annotated Concept	**<<Agent>>**
Concept Terminology	**An organization and management of resources and responsibilities for addressing all aspects of emergencies, in particular preparedness, response and initial recovery steps.**

Concept relationship

#	Domain Relation	Concept Relation	Annotated Concept	Ralationship cardinality	Relationship name	Relationship type
1	Uses	Coordination	<<Activity>>	1..* To 1..*	Requires	Association
2	ParticipatesIn	Command	<<Activity>>	1..* To 1..*	Follows	Association
3	Uses	Communication	<<EnvironmentEntity>>	1..* To 1..*	Uses	Association
4	Pursues	ResponseGoal	<<Goal>>	1..* To 1..*	WorksTowards	Association
5	ParticipatesIn	ResponseTask	<<Role>>	1..* To 1..*	Performs	Association
6	ParticipatesIn	Rescue	<<Activity>>	1..* To 0..*	Performs	Association
7	Uses	EmergencyOperationCentre	<<EnvironmentEntity>>	1..* To 1..*	Controls	Association
8	-	ResponseOrganization	CentralConcept	0..* To 1	IsAGroupOf	Aggregation

Figure 5.8 A DMM concept, its annotations and relations to other concepts, an example.

The annotated DMM-based repository also shows the domain relations and other concepts where a particular concept relates to or related from (A relation goes both sides). This is illustrated in Figure 5.8. For instance a DMM concept: *EmergencyManagementTeam* is annotated with FAML metamodel concept <<*agent*>>. The other eight (8) concepts and their annotations related directly to that particular concept are *Coordination <<Activity>>*, *Command <<Activity>>*, *Communication <EnvironmentEntity>>*, and so forth (See Figure 5.8). The domain relations connect *EmergencyManagementTeam* to those other concepts to be able to be understood effectively by the stakeholders. In this context, a representative relation is put in between the related concepts. It means the *EmergencyManagementTeam* as *<<agent>> Involves Coordination* and *Command* as *<<Activity>>*, *Uses Communication* and *EmergencyOperationCentre* as *<<EnvironmentEntity>>*, to *Pursues ResponseGoal* as *<<Goal>>* and *Plays ResponseTask* as *<<Role>>*. This understanding applies to both sides and to other relations. For instance, as can be seen from Figure 5.8, R*esponseTask* is related directly to two concepts: *EmergencyManagementTeam* and *ResponseGoal*. This informs that *ResponseTask* as *<<Role>> is Played* by *EmergencyManagementTeam* as *<<Agent >>* to *Pursues ReponseGoal* as *<<Goal>>*.

The way the concepts are structured and how they are related essentially is the foundation of a comprehensive and holistic decision making mechanism. This is because once a concept is identified the other relevant and essential concepts are also identified which in turn will help the stakeholder to identify the relevant knowledge completely. These annotations configure the repository to be used to facilitate the transferring process. The next stage is transferring the DM knowledge extracted in Stage 1 to this annotated DMM-based repository. This is elaborated on in Stage 3.

5.2.4 Stage 3: Knowledge transfer

In this stage, the transfer process of the knowledge in Wagga-Wagga ABMs to the annotated DMM is undertaken. This is a semi-automated process engaging a DM practitioner to intervene as required. For the purposes of depositing the knowledge from the AOA stage to the repository, the database is developed as shown in Figure 5.9. The database tables are the representation of the knowledge of the ABMs that are analysed and structured in the XML file (See Figure 5.6). The XML format allows both machine and human readability. Thus, it is considered an effective format for codifying the knowledge. However, for manipulating the knowledge, for instance to synthesize the knowledge elements from different ABMS to which it contains the necessary elements for a decision making process or in the annotation process for knowledge transformation, SQL is the language designed for this particular capability. Thus, it needs to be stored in a rational database management system format prior to enabling the manipulation. The tables are related representing the relations between the knowledge elements. Moreover, the cardinality degree is provided to determine whether their relationships are one-to-many (otherwise many-to-one) or a many-to-many. In database terminology, the figure is called an Entity Relational Diagram (ERD). In addition, these relationship types determine how data stored in the scheme will become the knowledge in the retrieving processes or remain as it is. This is undertaken by specifying a set of querying to extract the knowledge elements and relate them in a way that is understood by the end users.

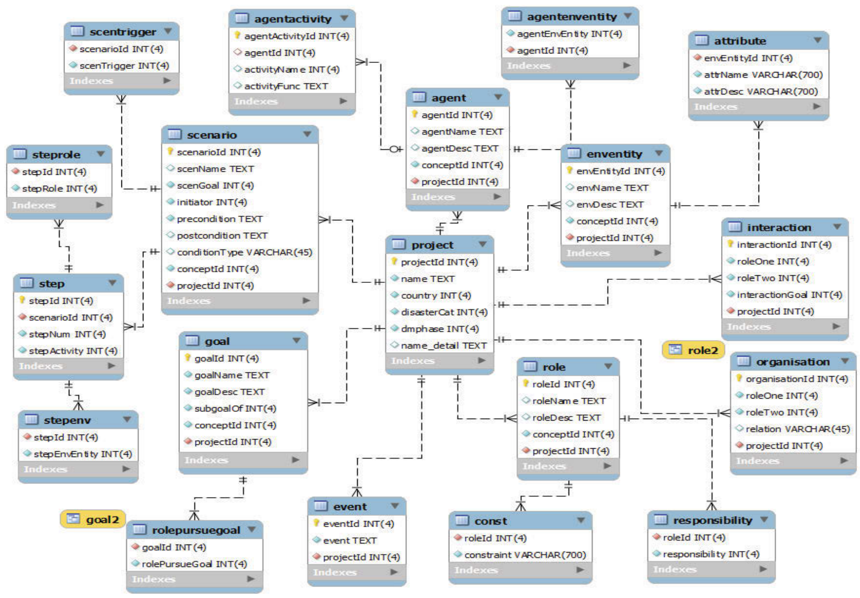


Figure 5.9 ERD of the WW DISPLAN knowledge elements.

In the transfer process, the WW flood DISPLAN knowledge structured in each of the corresponding ABMs is annotated with each of the corresponding FAML metamodel constructs in the repository. In this evaluation process, the WW flood DISPLAN knowledge managed in XML file needs to be transferred into the database scheme. Subsequently, mapping each of the ABMs with the appropriate DMM concept is performed. In this stage, a knowledge engineer is involved to intermediate this process.

With respect to the MOF framework, the knowledge in *M0* layer that undergoes AOA is modelled and structured in *M1* layer. The knowledge is transferred to its appropriate metamodel-based repository in *M2* layer, (*(M0→M1)→M2*). This process is mediated by a knowledge engineer based on the semantic meaning between each of the ABMs of DISPLAN knowledge and the most appropriate concept in the repository. If there is only one appropriate annotated DMM-based concept in the repository to which an ABM is a match with, then the transfer process can be proceed automatically. If, however, there is more than one possible annotated DMM-based concept in the repository, then a DM expert intervention is required to determine which concept, among all possibilities, is more appropriate for the ABM to be positioned and transferred to. The intervention is based on the semantic meaning of them. This is due to the fact that a human is still the best interpreter.

Figure 5.10 shows an example when there is only one representative concept in the DMM for one particular ABM. The transfer can proceed directly and automatically. This is transferring the *goal models*. As there is only one concept in the DMM repository representing the *goal models*, namely *ResponseGoal* concept then all the *goal models* are transferred directly to it. All the 89 (eighty-nine) knowledge elements of *goal models* are positioned automatically to the *ResponseGoal*. Figure 5.11 on the other hand shows an example when there is more than one potential target concept in the repository. A knowledge engineer intervenes in this case by mapping those associated concepts between concept in model and the metamodel. Figure 5.11 shows the mapping process of the knowledge related to environment. There are 11 (eleven) possible concepts in the DMM repository where the *environment model* is able to map with, namely: *Emergency Plan, Communication, Standard Operating Procedure, Victim, Emergency Operation Centre, Resource, Aid, Humanitarian Aid, Development Aid, Bilateral Aid* and *Exposure*. A knowledge engineer identifies the most appropriate concept to be mapped to each of the knowledge elements of the *goal models*. The concept selection is based on their semantics.

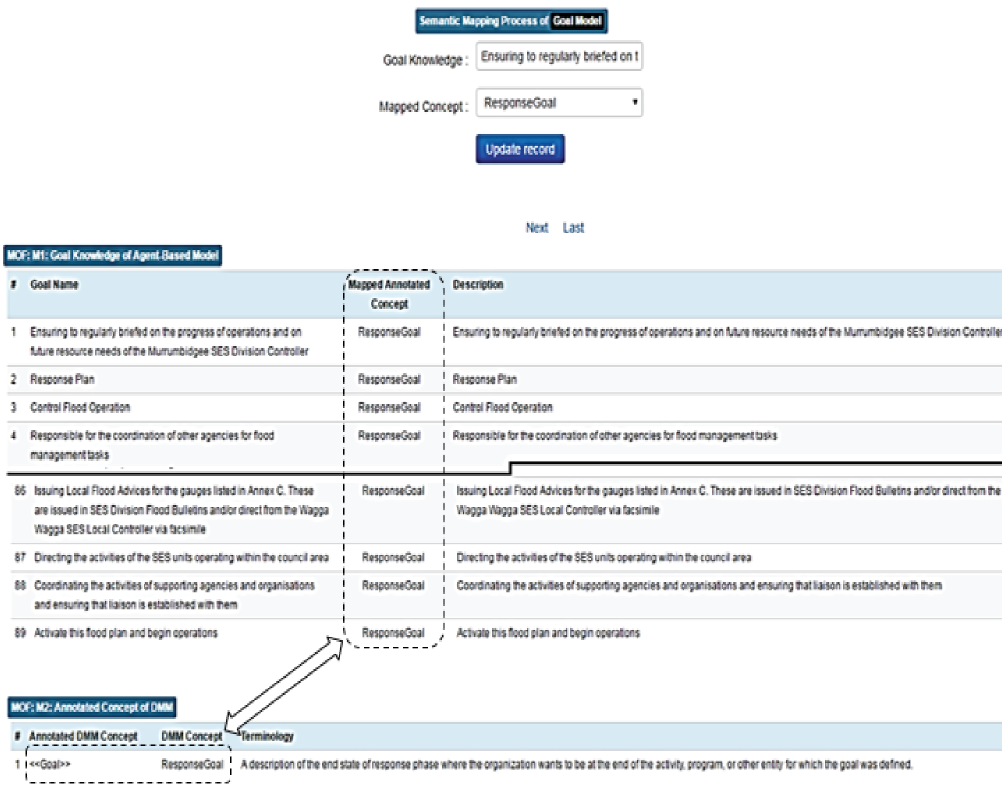


Figure 5.10 The mapping process of *goal model* of WW DISPLAN knowledge to its corresponding DMM concept in the repository for the Response phase.

The mapping process in the tool developed automatically limits those candidates of DMM concepts appearing in the list of appropriate annotated DMM concepts. In Figure 5.10, the system limits to only the *ResponseGoal* concept of the DMM that appears in it where the *goal model* is aimed to map with. Similarly, in Figure 5.11, the system limits only those 11 (eleven) concepts to be appeared to ease the knowledge in the mapping process of the *environment model*. The knowledge elements which appear are the ones related to the environment knowledge. Other concepts that are not related are omitted. This in turn assists the DM practitioner in having broad awareness but concise visibility of the related knowledge, processes, and concepts that they must apply within the DISPLAN and the overarching DMM. In this evaluation stage, the environment knowledge, for instance: "*list of agencies and organisations*", "*list of other agencies*", "*The resources of distribution*", "*The resources to be deployed*" are mapped to the *Resource* concepts. These environment knowledge elements describe the resources to be used to support the DM activities which therefore have commonality with one of the *Resources* concepts semantically. As such, the knowledge engineer maps them accordingly.

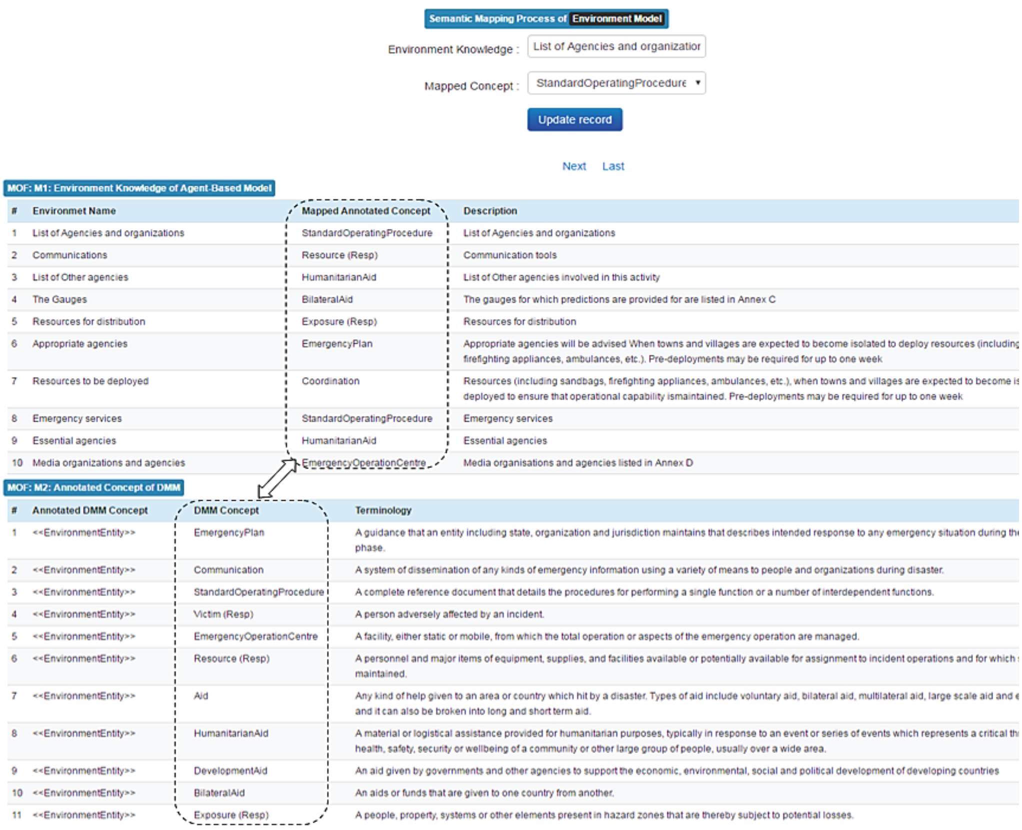


Figure 5.11 The mapping process of *environment model* of WW DISPLAN knowledge to its corresponding DMM concept in the repository for the Response phase.

The transfer process is applied iteratively in all mapping activities between all ABMs of flood WW DISPLAN knowledge and their corresponding annotated DMM-based concept until all of them are fully mapped. In the repository, the three components: DM phases, the MOF framework and the ABMs construct the knowledge in a three-dimensional (3D) structure which allows the knowledge to be drilled down or rolled up efficiently and effectively within the time frame of the DM activities. This is illustrated in Figure 5.12 where the *goal models* and *environment models* of WW flood DISPLAN knowledge of the Response phase are shown respectively as the exemplars in this thesis. Therefore, only both AOSE metamodel concepts <<*goal*>> and <<*environmentEntity*>> are highlighted in that figure. To complete the 3D knowledge structure, these three stages are undertaken iteratively. Eventually, this knowledge structure allows the knowledge to be reused by pinpointing the appropriate knowledge through each cube of the structure as necessary, holistically, and comprehensively.

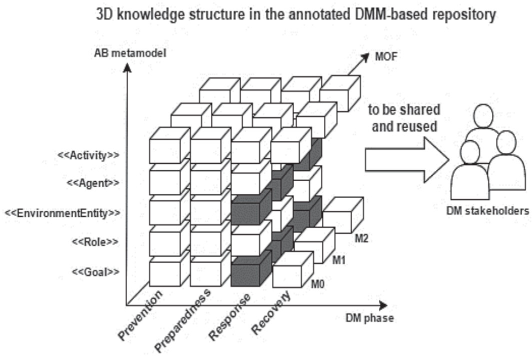


Figure 5.12 A three-dimensional (3D) knowledge structure in the repository. Only the goal and environment knowledge in Response Phase are highlighted as the exemplars of the mapping process.

5.3 DM Knowledge Structure in the repository

The main objective is to develop a framework facilitating the knowledge transfer analysis in DM domain. In Section 5.2, the first evaluation showed how the knowledge elements in the DISPLAN is extracted and transferred into the representative repository. In this section, we show how the repository can be accessed. Figure 5.13 shows how the knowledge elements of WW flood DISPLAN deposited in the DMM-based repository is structured. The structure enables the stakeholders to develop an explicit explanation of their decision-making process for one particular scenario within the DM timeline.

In the new representation of the DISPLAN, the knowledge is holistically and comprehensively produced. ‘Holistically’ means that for that particular identified concept, the knowledge can be drilled down from and rolled up to the decision making to planning/policy to real work knowledge layers, respectively. ‘Comprehensively’ means that once a knowledge concept is identified for one particular DM activity, other concepts that are related to it directly are also be effectively recognised. ‘Effectively’ means that the DM knowledge is based on the best practice for a particular disaster in a geographic area, and at the same time the knowledge is structured so that the users are able to retrieve it in a way that it can be comprehended effectively.

As can be seen in Figure 5.13, a concept: *EmergencyManagementTeam*, its relationships and how it is related to other concepts are shown. This is a concept in Response phase of DM framework describing agents involved in activities. Essentially this concept is the abstract representation of the DM activities therefore it is positioned as *M2*.

Concept relationship

#	Domain Relation	Concept Relation	Annotated Concept	Ralationship cardinality	Relationship name	Relationship type	
1	Uses	Coordination	<<Activity>>	1..* To 1..*	Requires	Association	
2	ParticipatesIn	Command	<<Activity>>	1..* To 1..*	Follows	Association	
3	Uses	Communication	<<EnvironmentEntity>>	1..* To 1..*	Uses	Association	
4	Pursues	ResponseGoal	<<Goal>>	1..* To 1..*	WorksTowards	Association	1
5	ParticipatesIn	ResponseTask	<<Role>>	1..* To 1..*	Performs	Association	
6	ParticipatesIn	Rescue	<<Activity>>	1..* To 0..*	Performs	Association	
7	Uses	EmergencyOperationCentre	<<EnvironmentEntity>>	1..* To 1..*	Controls	Association	
8	-	ResponseOrganization	CentralConcept	0..* To 1	IsAGroupOf	Aggregation	

M1: Disaster Management (DM) Model

Model Name	WW_Flood_DISPLAN_Resp_fixed	DM phase	Response	Disaster Category	Climatological Disaster	2
Country Origin	Andorra	Disaster Type	Extreme Temperatures	Class of Disaster	Natural	

Initiator	: SESLC	
Pre-condition	: -	3
Post-condition	: -	
#	Scenario Name : Rescue	4
1	Control flood rescue	5

M0: Disaster Management (DM) real world knowledge model

#	The Trigger of the Activity(ies)	
1	When flooding is expected to be severe enough to cut road access to towns, within towns and/or rural communities	
2	On receipt of a Bureau of Meteorology Preliminary Flood Warning, Flood Warning, Flood Watch or Severe Weather Warning for Flash Flooding	6
3	On receipt of dam-failure warnings for Burrinjuck, Blowering or Talbingo Dams	
4	When other evidence leads to an expectation of flooding within the council area	

Condition	#	Activity(ies): Control flood rescue	Activity(ies) Involves Role(s)	Activity(ies) Needs Environment
interleave	1	Carry out flood rescue using high clearance vehicles, flood boats and (under some circumstances) helicopters	Role	Env
10	2	Request additional flood boats and crews through the Murrumbidgee SES Division Headquarters 7	Role 8	Env 9
	3	Arranging evacuation for the Wagga Wagga City Council area as listed in Annexes F to O	Role	Env

Figure 5.13 The knowledge holistically and comprehensively is structured for a decision making process in the Response phase of flood DM. The knowledge is traceable up and down from the conceptual (*M2*) the planning/policy (*M1*) and real world activity (*M0*).

In Figure 5.13(1), all the related concepts to that particular concept are shown, namely: *Coordination, Command, Communication, ResponseGoal, ResponseTask, Rescue, EmergencyOperationCentre and ResponseOrganisation*. The knowledge can be retrieved by ‘clicking’ on any of these concepts. The figure also shows the domain relations for each of their relations. These relations show the benefit of the DMM-based repository as the explicit representation of these relations can provide an invaluable guide in retrieving the appropriate knowledge (this will be explored further in a post evaluation in Chapter 6). Figure 5.13(2) describes the information regarding the originality of the knowledge: where it comes from and in which disaster it is used for. While Figure 5.13(3) shows the pre, post-condition and the initiator of the main goal, Figure 5.13(5) informs the typical knowledge in the *M1* layer, for instance, the knowledge element presented is “*control flood rescue*”. This knowledge is inherited from its concept 15(4): *Rescue* where it is one of the concepts that relates directly to the one: *EmergencyResponseTeam*. While the knowledge in the *M0* layer describing the real word activities is defined in Figure 5.13(6), (7), (8), (9), in 5.13(10), the knowledge represents the *trigger* of the activities, the *activities* themselves, the *roles* that are responsible for each of the activities, the environment to be used in to accomplish the activities and the condition that the activities are undertaken in interleaved manner, respectively.

5.4 Conclusion and Discussion of the Case Study in Wagga-Wagga

The main goal of this evaluation case study is to ascertain if the developed framework to convert to DMM-based repository works as intended. The knowledge from the Wagga-Wagga (WW) flood DISPLAN knowledge document is employed to validate the developed. The evaluation shows that the process leads to effective transfer of the knowledge contained in the DISPLAN into the repository. At the end, the system enables better access, sharing and maintenance of the knowledge. During the case study, issues emerged in the efficiency of the conversion process. These are discussed and analysed in this section.

Firstly, the DISPLAN contains multiple goals which do not necessarily relate. In the analysis of the plan, it is worth focussing on a single goal and producing all models emanating from the goal before switching the attention to another goal. In other words, a depth-first approach is a more efficient approach which enables the modeller to produce the subsequent models (emanating from a goal model) more effectively. A depth-first analysis of goals can also potentially enable multiple modellers to collaborate in converting the same plan.

Secondly, many knowledge elements produced at *M0* level during the conversion were too specific to Wagga-Wagga. This will clearly be the case for another DISPLAN from a different area. With appropriate abstractions, such elements can be reused by other DM stakeholders, as they may well represent common activities and they need to be perceived as such at the planning/policy layers. An example is: "*Providing Blowering Dam failure information*". This is specific to Wagga-Wagga where the Blowering Dam is built. This element is difficult to reuse in other areas as a different dam may exist. Another example is the role of Wagga-Wagga SES Local Operational Controller (WWSESLOC) involved in pursuing many DM activities in Wagga-Wagga. In other areas, the name of the role might be still the same, the SESLOC, but it may well be another person. Thus, for the developed framework to be more efficient (and effective in this case), instead of a unique DISPLAN knowledge, a template can be considered as the input of the framework. The template serves as a common ground to be adopted by the stakeholders to subsequently generate the specified local DISPLAN for each of them.

It is also worth noting that some concepts in the DMM appear redundant and conflicted at the same time. For instance, in the Response phase, the *Incident* and *Disaster* concepts are annotated by the same AB concept <<*Trigger*>>. This is because both concepts have the same semantic meaning as in the AB <<*Trigger*>>. However, the issues are that (1) both concepts essentially refer to the same thing. Therefore, they are redundant; (2) their relations do not always reflect an intention that is significant for decision making. For instance, apart from the relation to the concept *Incident*, the concept *Disaster* also relates to the concepts *Exposure* and *InformationManagement*. While the concepts *InformationManagement* is annotated by AB concept <<*Activity*>>, this means that the *Incident* drives a set of activities organised in the concept *InformationManagement*. This essentially translates as knowledge elements in the *scenario model*. On the other hand, the relation of the concept *Incident* and *Exposure* is not reflected in any other ABM. Thus, the DMM might be readjusted for the best practice in this case. However, although this is a worth finding from this evaluation, this is a DMM-related issue which the thesis is not aimed to address.

5.5 Chapter Summary

This chapter examines the first evaluation of our developed framework. It is conducted with a real case study of the WW flood DISPLAN document knowledge from the SES NSW agency, the authoritative agency to combat flood disaster in the NSW regions. The evaluation is conducted thoroughly encompassing the whole dimensions of the framework. The semi-structured knowledge of WW flood DISPLAN document is the input at the first stage of the developed framework. A knowledge engineer analyses and models the knowledge in the WW DISPLAN as structured in each DMM phase. Subsequently, each of the knowledge elements in ABMS is assigned as either planning/policy (*M1*) or real world activities knowledge (*M0*). In particular, the process related to whether the knowledge is appropriate for the planning or real world activity can be identified.

The evaluation successfully illustrates the conversion of the actual flood DISPLAN used by WW SES municipality on the Murrumbidgee River in NSW to the metamodel based representation. A web-based interface is implemented as a prototype to assist the effectivity of the evaluation process. The process focuses on resolving a set of key issues on how knowledge is typically stored, shared and accessed by participants and by communities in DM. This evaluation illustrates the effectiveness of the mapping process. At the end, the knowledge is structured in a 3D layer representation. Each layer corresponds to a more abstract view of DM knowledge, from event, to policy to the metamodel. Each layer consists of generic DM constructs which can be used to index DM knowledge during knowledge retrieval with respect to the disaster event context. Eventually, these constructs can be mixed and matched between the DISPLANs. By utilizing the DMM-based repository the stakeholders are capable of seeing the relationships and the knowledge they have with other entities in achieving the goals through a set of activities undertaken across all PPRR (Prevention, Preparedness, Response and Recovery) phases.

Due to the significant size of the DM knowledge involved, efficiency of analysis is a key requirement. Two issues emerged in this case study: 1. The need for an intermediate abstraction (i.e. a template) to avoid usage of area specific names 2. The need for a depth first agent oriented analysis process to ensure that the knowledge engineer remains focussed on the elaboration each *goal model*. These issues will be rectified in the next version of the framework which will be presented in Chapter 6. Chapter 6 will also use another SES case study (Wollongong instead of Wagga-Wagga) to further ensure its generalisability. Chapter 6 will also conduct a post evaluation of the knowledge extracted from the DISPLANs to ensure that the knowledge is reusable by a DM expert.

6 The 2nd framework evaluation: *Using Templating and Depth-First Goal Analysis*

In the previous chapter, the framework underwent its initial evaluation. The evaluation successfully showed that the framework enables the conversion of a flood DISPLAN knowledge of the SES NSW into the repository. The evaluation demonstrated the conversion but it also highlighted scope for improving its efficiency. In this chapter, two efficiency enhancements to the framework will be added and further validated:

1. The first enhancement will make use of existing DISPLAN templates.
2. The second enhancement will provide a process to guide a knowledge engineer in a way to reduce the need to revisit the same sections of the DISPLANs. A depth-first approach is then introduced to guide the knowledge engineer.

In addition to the efficiency enhancements, a post-evaluation process is also performed in this chapter to ascertain the usability, accuracy and the benefit of the knowledge representation structured in the DMM-based repository. The post-evaluation is conducted in collaboration with a DM expert from SES NSW.

This chapter is organised as follows: In Section 6.1, the significance of knowledge template adoption will be elaborated. Section 6.2 elaborates the stages of the improved framework. Section 6.3 describes illustrates the performance of the framework in transferring the knowledge in the flood plans of Wollongong Municipality to the repository. 6.4 describes a post-evaluation to ascertain the benefit and usability of the knowledge in the repository. Finally, Section 6.5 presents the conclusion and discussion of the chapter.

6.1 DM knowledge template significance

The framework targets at processing a large connected but disparate knowledge sources currently maintained as individual text documents. Emergency services covering a wide range of hazards develop DISPLANs of various structure and intent. In general, the plans are created as instances of centrally developed templates, for example, those which are developed by the NSW and

Victorian SES's State planning policies. The structured DISPLAN knowledge of the cities/municipalities in each State show commonality as they are developed using the same typical template; however, there is also local expert knowledge added to each instance. As a template, all the relevant and observable knowledge elements will be included and identified. The template serves as a general guideline for the agencies to develop their own DISPLANs by adjusting them to their local resources and environments.

Eventually, each of the cities themselves will decide which knowledge will be appropriate. In other words, each of the cities will inherit the knowledge from the template and customise it with respect to their local conditions and situations. This is illustrated in Figure 6.1. In the case of a State level DISPLAN, the template can be employed to generate the plans for all municipalities/cities across the State, as they are all under the same hierarchy level. Therefore, all instances automatically conform to their template. For instance, in NSW, Australia, all the cities and regions across the State adopt the same DISPLAN template for flood disaster developed by the SES NSW. The template is developed as a classifier which is used by the SES NSW in each region and its cities to instantiate their specific DISPLANs. These particular DISPLANs adapt and adjust the customised template based on their resources and environments. This can also be observed in other states in Australia, for instance, the State of Victoria, for a similar disaster. This evaluation has been exhibited partly in here (Inan *et al.*, 2016).

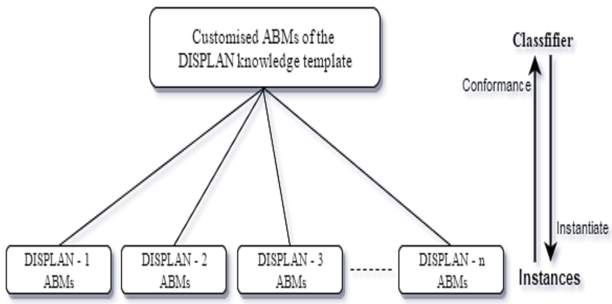


Figure 6.1 Template and the DISPLANs relationship.

Due to the significant size of the DM knowledge involved, efficiency of analysis is a key requirement. Thus, the analysis framework is improved to begin with the DISPLAN knowledge template, rather than a unique localised plan. The use of templates as the input instead of a unique plan increases the effectiveness and efficiency of the analysis by first tuning the ABM templates to suit the core structure of all DISPLANs. In this context, effectiveness relates to the adoption of the process in which the modellers producing customised ABMs are able to more quickly generate many instances of DISPLAN that are strongly based on the core template but are specific to localised parameters. This mirrors the approach taken by emergency management agencies. They typically harness the use of templates so that if any ratification of changes or updates occur, these can be easier promulgated and adapted in any instance of localised plans. The use of templating is also common as it is seen as a key approach to effective interoperability as it helps stakeholders to quickly identify the urgent and relevant knowledge to respond to a particular activity by developing a familiar construct of actions which can easily be navigated.

6.2 Knowledge Analysis Framework of the second evaluation

The main stages of the knowledge analysis framework in this second evaluation remain unchanged but a knowledge template is to be used as input to the framework instead of the local plan itself. While this amendment anticipates the input into a general template format, as highlighted in the previous section, this kind of input is typically available or easily adopted. To process this input (i.e. templates) the first stage of the framework is revised. Now, the knowledge engineer first customises ABMs with respect to the DISPLAN template. The knowledge engineer is then able to synthesise and adjust these customised ABM with respect to the environment and local resources of that city/municipality as would be described in the individual DISPLANs themselves.

The subsequent AOA begins with the customised ABM templates. For this stage, the framework is also improved. It now enforces a strict depth-first approach where every goal model is analysed to maximal conclusion before the analysis of another goal model begins. This ensures that the knowledge engineer maximises their use of the elements in a given goal model towards producing the other subsequent models. This essentially reduces the number of revisits of the DISPLAN document, thereby further improving the efficiency of the analysis process. This approach also enables collaboration of multiple modellers in converting a given plan into the repository. For instance, different modellers can focus on analysis paths along different goal models and further communicate during subsequent iterations. The agent models resulting from this process are then transformed into the repository following a specified semantic mapping. The knowledge structured in the repository can then be and shared and reused by other users for their DM activities. The improved knowledge analysis framework is shown in Figure 6.2. It consists of three main stages, as follows:

Stage 1: The input to this stage is the DISPLAN template. In this stage, the template serves to customise the seven ABMs. The output of this stage is the set of customised ABMs. The linking to MOF abstraction layers is now done in the customised ABMs (rather than the actual models – which was the case in the first version of the framework in Chapter 5).

Stage 2: The customised ABMs from Stage 1 are then used to guide the required analysis of the actual DISPLANs. This process results in the ABM DISPLANs. The stage begins with goal modelling. A depth-first approach is enforced in this improved version of the framework. A modeller begins with identifying all knowledge following from one goal and subsequently identifies all resultant models. This way the knowledge engineer is able to reuse elements in the *goal model* and this incurs less revisits to the original DISPLAN.

Stage 3: This is the knowledge transformation process. This stage remains the same as elaborated in Chapter 5.

The remainder of this section details each of the stages of our knowledge analysis framework.

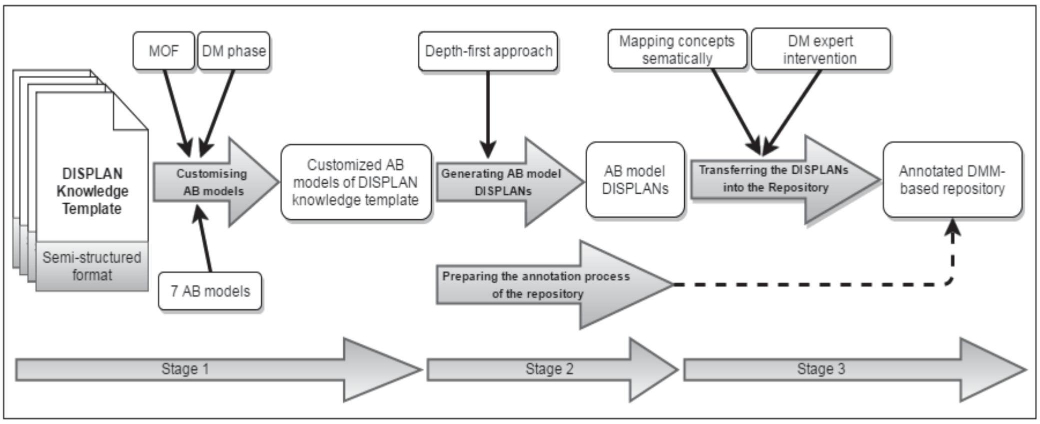


Figure 6.2 Three main stages of knowledge analysis framework of the second validation.

6.2.1 Stage 1: Customising Agent-Based Models

A DISPLAN template describes the structure of every DISPLAN within a state jurisdiction. It has knowledge that is common to all plans, for example contact details within the state or the names of roles. The template is in a semi-structured format and covers all four PPRR phases. The use of template DISPLAN instead a unique plan in this customising process underlies the first improvement that differs from the initial one discussed in previous chapter. In this step, the commonalities captured and expressed in the template are transferred to the ABM templates. That is, each AB template undergoes four steps in this customisation:

1. Common knowledge elements are transferred to the ABM templates.
2. Each ABM template is reduced in size to delete elements that are not required. That is, only the required elements are used in the ABMs.
3. Each element in the model is marked as either M0 or M1 (this later acts as a pointer in the transfer in Stage 3).
4. Each element in the model is marked with potential target DMM concepts (this acts as another point in the transfer in Stage 3).

The details of these customising processes of ABMS are as follows:

6.2.1.1 Customising the goal models

The customization process for the *goal model* is exemplified in Figure 6.3. The process essentially is that the DISPLAN template is analysed and modelled into the *goal model* template. A knowledge engineer anatomizes each of the knowledge elements in the DISPLAN template to position them in the corresponding element in the *goal model* template. This activity results a customized *goal model* of DISPLAN knowledge.

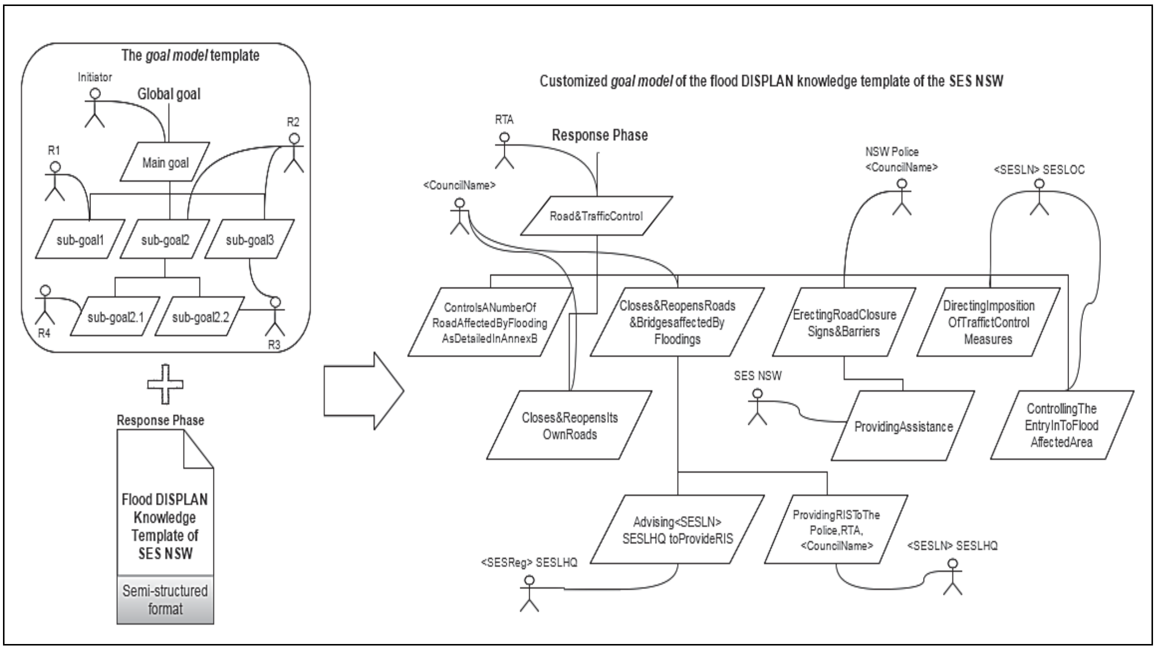


Figure 6.3 Customising the *goal model* and a DISPLAN template.

6.2.1.2 Customising the role models

As in the *goal model*, customising of the *role model* is carried out by analysing the knowledge elements in the DISPLAN template to model them in the appropriate ones in this model template. A knowledge engineer initially customizes the *role model* template based on the knowledge elements in the DISPLAN template. However, as discussed in the previous chapters, the ABMs are closely correspondent ones; this means that those models share the same knowledge elements. The knowledge engineer needs only to revisit the *goal model* to be able to model this model. This is by far also effective and efficient as this approach prevents inconsistency of the knowledge elements in the models referring to the same meaning. This process results in a customised *role model* of the DISPLAN knowledge template as described in Figure 6.4.

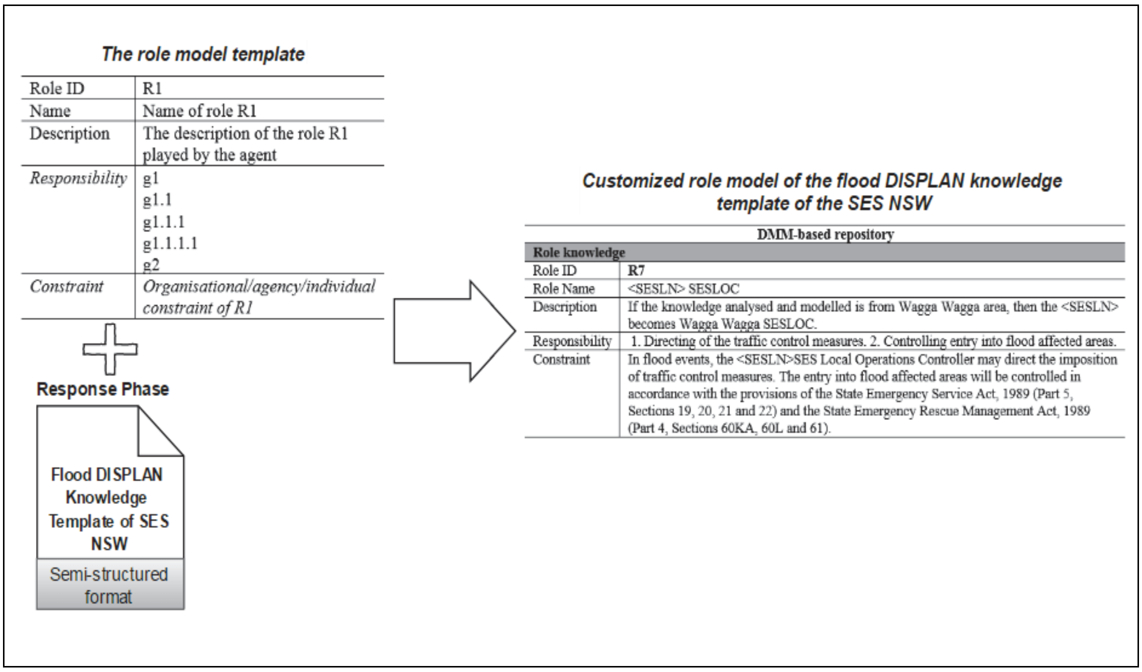


Figure 6.4 Customising the *role model* and a DISPLAN template.

6.2.1.3 *Customising the organisational models*

The next model to be customized is the *organisation model*. The knowledge elements in the *organisation model* refer to the *goal model* template for the effectivity and efficiency, particularly in identifying the involved role elements instead of revisiting the DISPLAN. The customization process of this model is exemplified in Figure 6.5. This process produces a customized *organisation model* of the DISPLAN template.

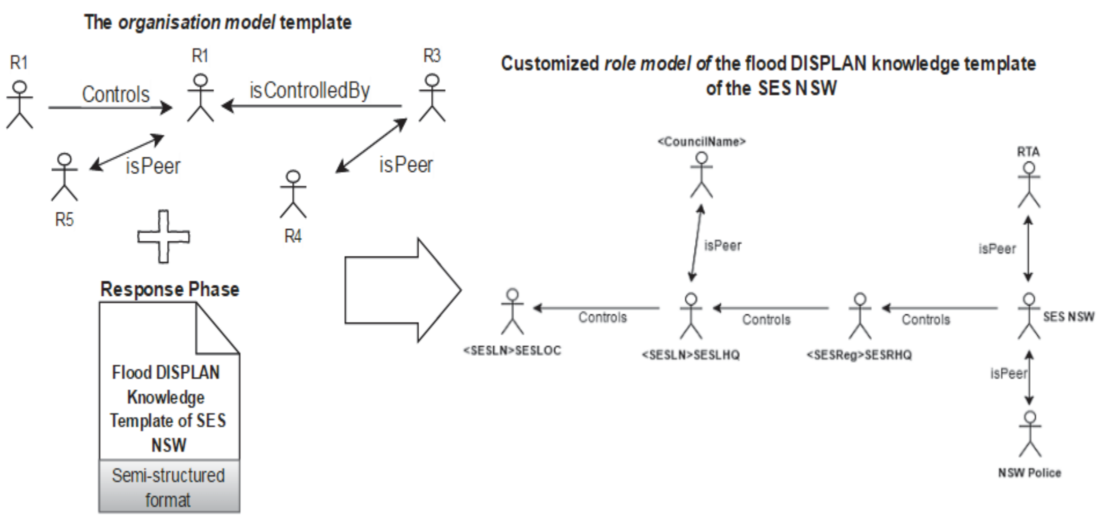


Figure 6.5 Customising the *organisation model* and a DISPLAN template.

However, to customise the relationships between the roles, a knowledge engineer needs to revisit the DISPLAN templates to be able to model them and subsequently place them into the corresponding elements in the *organisation models*. This process produces a customized *organisation model* of the DISPLAN template.

6.2.1.4 Customising the interaction models

In customising the *interaction model*, a knowledge engineer leans on the *goal model*. In the *goal model*, whenever more than one role is involved in a sub-goal, it means those roles are responsible for it, which therefore they will be interacted with to perform that. The customization process for the *interaction model* is illustrated in Figure 6.6.

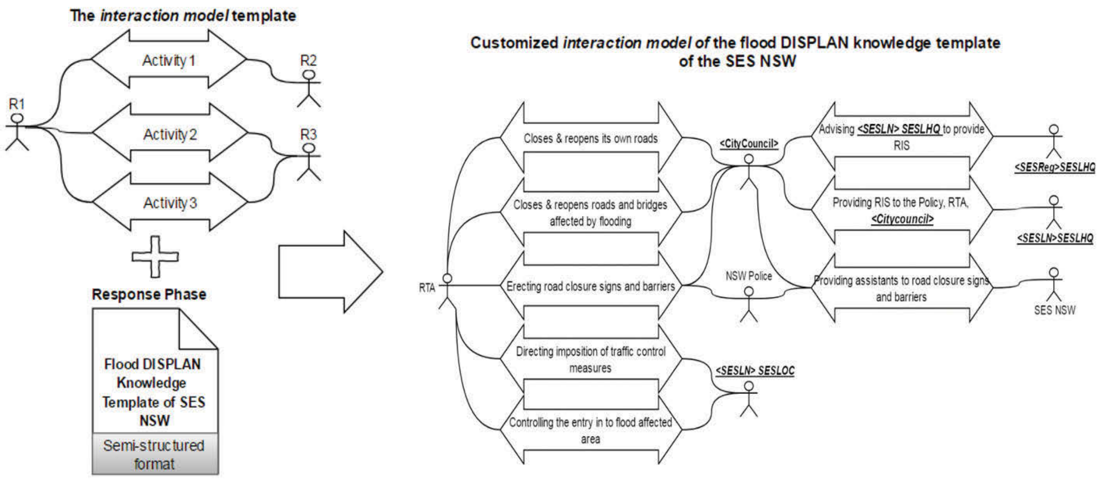


Figure 6.6 Customising the *interaction model* and a DISPLAN template.

This model represents those interactions. Thus, in the customisation, a knowledge engineer observes the *goal model* template to be able to model the *interaction model* effectively and efficiently without revisiting the DISPLAN document. This results in a customized *interaction model* of the DISPLAN template.

6.2.1.5 Customising the environmental models

As in the previous models, the *environment model* also undergoes a customisation process. A knowledge engineer analyses the knowledge elements in the DISPLAN template subsequently positioning them in the corresponding element in the *environment model* template. This process generates a customized *environment model* of the DISPLAN template. The customization process for this model is illustrated in Figure 6.7.

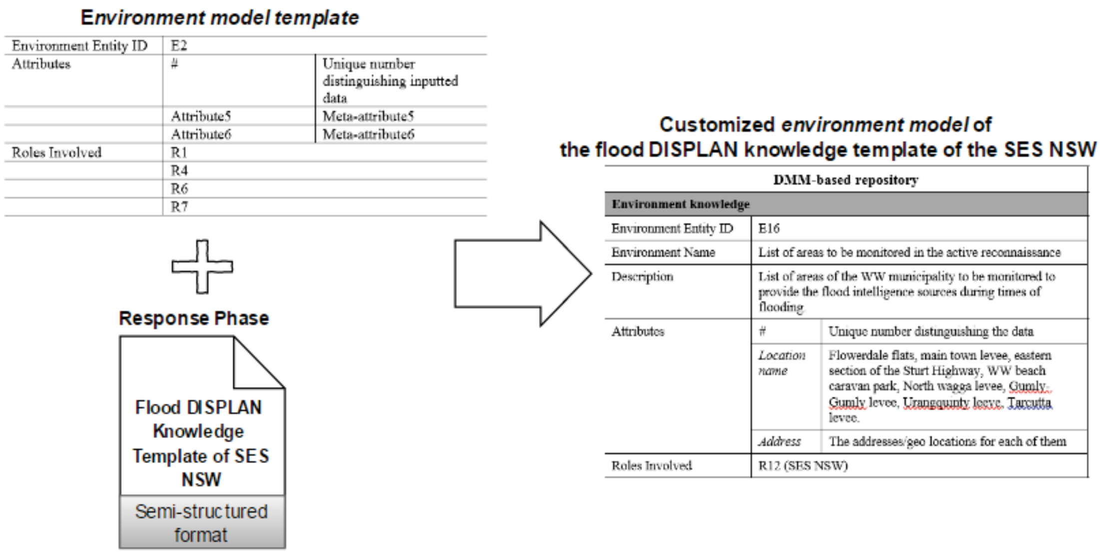


Figure 6.7 Customising the *environment model* and a DISPLAN template.

6.2.1.6 Customising the agent models

In the customising process of *agent model*, a knowledge engineer analyses the knowledge elements in the DISPLAN template and models them in this model template. All the elements in the document template are placed in the corresponding elements in the *agent model* template. As in the other models, the knowledge elements of this model template are obtained from the other models as they are closely correspond except for the *trigger* elements. The knowledge engineer needs to revisit the DISPLAN template to be able to analyse it. The result is a customised *agent model* of DISPLAN template as exemplified in Figure 6.8.

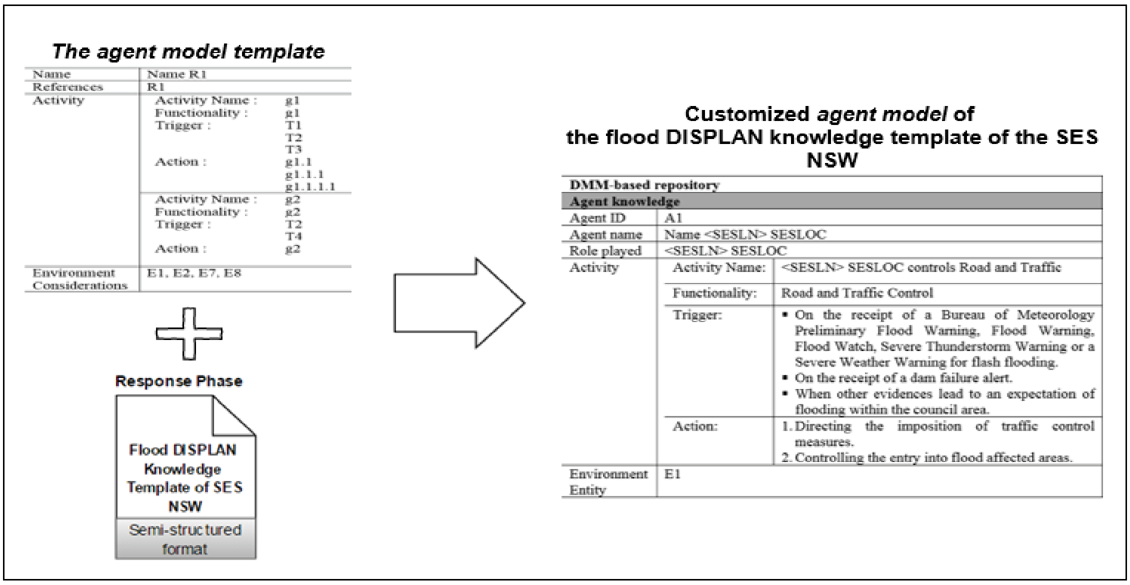


Figure 6.8 Customising the *agent model* and a DISPLAN template.

6.2.1.7 Customising the scenario models

The customising process is also applied in the *scenario model*. All the knowledge elements in this model are obtained from other models. This implies that the knowledge engineer needs to analyse this model based on the elements from other models without revisiting the DISPLAN template. This is exemplified in the Figure 6.9. This results in a customized *scenario model* of DISPLAN template.

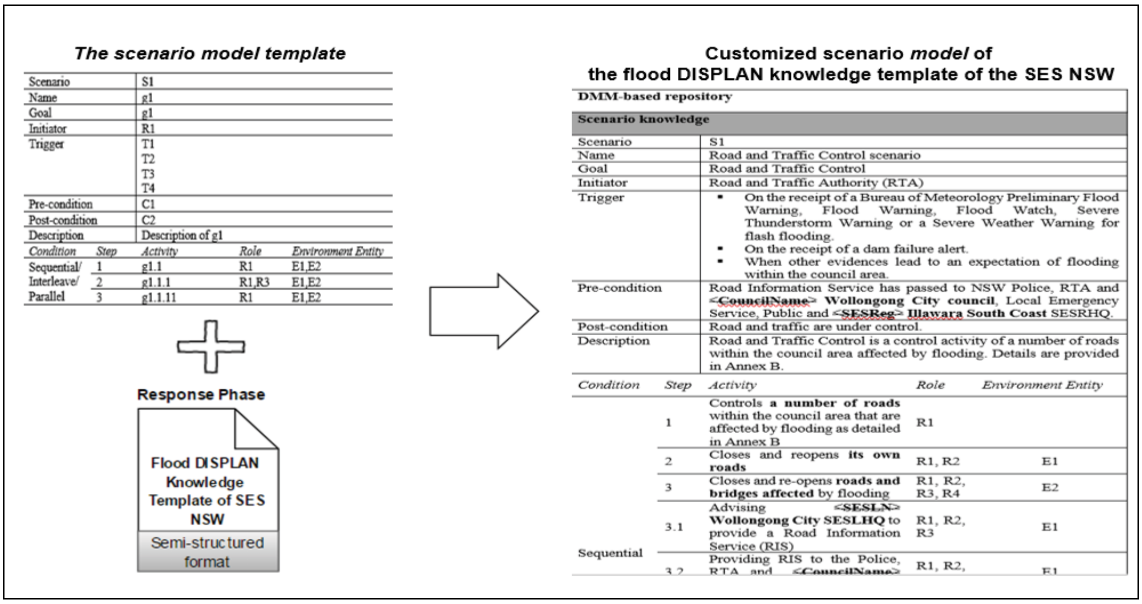


Figure 6.9 The *scenario model* template and a DISPLAN template.

6.2.2 Stage 2: Generating ABM DISPLANs

Once the customised ABMs of flood DISPLAN of the SES NSW are produced as discussed in Stage 1 then the ABMs corresponding to any unique flood plan for any area under the NSW State jurisdiction can be generated quicker. A depth-first approach guides the knowledge engineer in generating these models more efficiently. The engineer focuses to one particular main goal to complete a *goal model* first and then the other models before switching intention other main goals. This also enables multiple knowledge engineers to develop a particular DISPLAN (but this possibility is not pursued in this thesis).

The analysis process begins with generating the *goal model*. The seven adopted ABMs share knowledge elements with each other. Once one main goal is completely modelled then a modeller can process the next models. By generating the *goal model* first, and reusing knowledge elements from the *goal model*, the number of revisits to the DISPLAN is reduced rendering the process more efficient. Following the *goal model*, the *goal model*, *organisation model* or *interaction model* are generated. These three models can only be completed once the *goal model* is complete.

Knowledge elements of these models are linked to the *goal model*, although they are structured differently. The three models are followed by the *environment model* which can only be completed once the *goal model* is completed. For instance, the attribute role in the *environment model* needs to be extracted from the *goal model*. The *agent model* and *scenario model* are the last two to be completed. The knowledge elements of these two models depend on the content of the other models hence they are generated once all five others are completed.

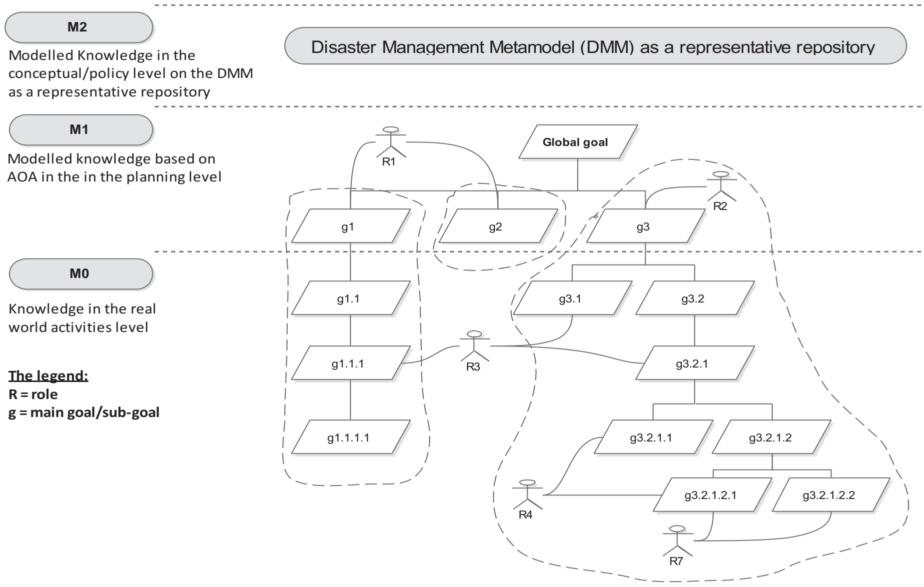


Figure 6.10 The AOA of a *goal model* in a depth-first search approach.

The analysis process is iterative and can separate analysis of the main goals and each of their sub-goals. i.e. later activities are identified to support earlier activities. For instance, in Figure 6.10, sub-goals *g3.1* and *g3.2* support the main goal *g3,* and/or the sub-goals *g3.2.1.1* and *g3.2.1.2* support *g3.2.1*, and so on. This enables a modeller to concentrate on completing one main goal at a time, without being distracted by the other goals/sub-goals. This can significantly reduce the complexities in the early requirement phase. The modeller analyses the main goal g1, and all its sub-goals from *g1.1* to *g1.1.1.1*, and roles *R1* and *R3*. All the sub-goals of a main goal can be traced as the activities to support and address the main goal. Since the role R1 is responsible for the main goal *g1*, it also implies that the particular role is responsible for all the sub-goals of the main goal. Thus, the role *R1* is automatically responsible for *g1, g1.1, g1.1.1* and *g1.1.1.1*. The *goal model* informs that for the sub-goal *g1.1.1,* there is another role, *R3*, involved in pursuing it. This notifies that the role R1 is responsible as the initiator for the main goal while both *R1* and *R3* will interact, communicate and coordinate in pursuing the sub-goal *g1.1.1*. These elements of the *goal model* will be the basis for identifying relationships between closely related ABMs.

The depth-first approach offers a systematic way to conduct a detailed AOA. It shows not only where to start the modelling activities (Lopez-Lorca *et al.*, 2016; Miller *et al.*, 2014) in the

AB paradigm, but also how to do it step by step rigorously. As shown in Figure 6.10, this illustrates that once the *goal model* is holistically analysed and modelled then a modeller can easily look at the model's elements as the cornerstone to process other ABMs without revisiting the knowledge in the document. For instance, the roles involved to pursue a sub-goal analysed in the *goal model* will be the basis to structure the *organisation model* and *interaction model*. The main goal and sub-goals of a *goal model* will be used to structure action in the *agent model* and activity in the *scenario model* and so on. These processes themselves are conducted iteratively, therefore the modellers can always go back to the previous stage to improve the modelled models.

By adopting the depth-first approach, the AOA can also be made more efficient by distributing the processes to a number of modellers. Modellers can share the AOA tasks to be undertaken in parallel. For a large knowledge DISPLAN, each modeller can focus on only one particular main goal and all its sub-goals at a time. At the end, these goals will be combined to represent one complete *goal model*. Once these *goal model*s are structured, the other ABMs can be analysed effectively and efficiently as their knowledge elements are obtained from the existing models. This approach enables interleaving of the modelling processes i.e. a modeller can activate the other models, without waiting until others' main goals are fully analysed in a complete *goal model*. This evaluation has been exhibited partly in here (Inan *et al.*, 2017).

6.2.3 Stage 3: Knowledge transfer

The knowledge transfer is similar as in the initial evaluation of Chapter 5.The two activities of this stage are: 1) Preparing the DMM-based repository; and 2) Transferring the DISPLAN ABMs to the prepared repository.

6.3 Case Study: the SES NSW Flood DISPLAN knowledge template

In this section, the revised framework of knowledge transfer analysis is validated. A second case study from SES NSW is used in this validation. As earlier described, a DISPLAN template is first acquired. That is a flood DISPLAN knowledge template of the SES NSW obtained as the first input of the framework. This input is used to customize the ABM templates to enable their more effective and efficient use (The customised ABMs of the flood DISPLAN of the SES NSW is included in Appendix D in this thesis). The ABM templates are then used to generate particular DISPLANs ABMs and these are then transferred into the repository. The particular DISPLAN chosen is the Wollongong Municipality Flood Management DISPLAN. The Wollongong DISPLAN is maintained to prepare for, manage the response to, and support recovery from flood disasters. It is maintained by SES NSW in conjunction with the Wollongong City Local Government and its representative Local Emergency Management Committee, comprising local stakeholders. The DISPLAN covers knowledge in three phases: Preparedness, Response and Recovery. The evaluation in this section is applied only to the Preparedness and Response phases. The three main stages of the transfer process for the Wollongong DISPLAN are illustrated in detail in this section. This evaluation has been exhibited partly in here (Inan & Beydoun, 2017).

6.3.1 Stage 1: Customising Agent-Based Models

In this stage, the seven ABMs are customised. The flood DISPLAN knowledge template of SES NSW is analysed to identify commonalities and model the commonalities into the ABM templates. In what follows, the customization of some of the ABM modelling templates is elaborated according to the conceptual description in Section 6.2.

6.3.1.1 Customising the goal model

In this case study, a main goal "*Road and Traffic Control*" is identified as an example from the flood DISPLAN knowledge template in SES NSW. It is a goal out of many and various goals in the document template (they are included in Appendix D of this thesis). The Road and Traffic Authority (RTA) is responsible to initiate this main goal which therefore is automatically as the initiator. As the initiator, this means that RTA is also responsible and involves in all sub-goals underneath. This means that the RTA automatically interacts with other role(s) that is/are responsible for other sub-goals. For instance, to perform the sub-goal "*Erecting road closure signs and barriers*", RTA interacts with NSW Police and <*CouncilCity*>. The customized *goal model* constructed following the MOF framework is shown in Figure 6.11.

Once this main goal: "*Road and Traffic Control*" is identified, the knowledge engineer then goes through the flood DISPLAN template of the SES NSW to identify its sub-goal(s) and role(s) for this particular main goal only, and omitting the other elements that are not related. For instance, in this example the sub-goals are: "*Controls a number of road affected by flooding as detailed in Annex B*", "*closes and reopens its own road*", etc. The roles responsible for the two sub-goals are: RTA and <*CouncilName*> respectively. The knowledge engineer then goes through to complete all other knowledge elements to complete them in the *goal model* as shown in Figure 6.11.

In the final customisation step, the knowledge engineer marks every knowledge element to highlight the likely MOF abstraction layer of the element (*M0* or *M1*). For instance, the main goal "*Road and Traffic Control*" is annotated *M1* as it represents the objective to be strived for, and all its remaining sub-goals will be marked for *M0*. This example only shows one customised *goal* *model* for that particular main goal as an objective to be accomplished out of many of them (included in Appendix D).

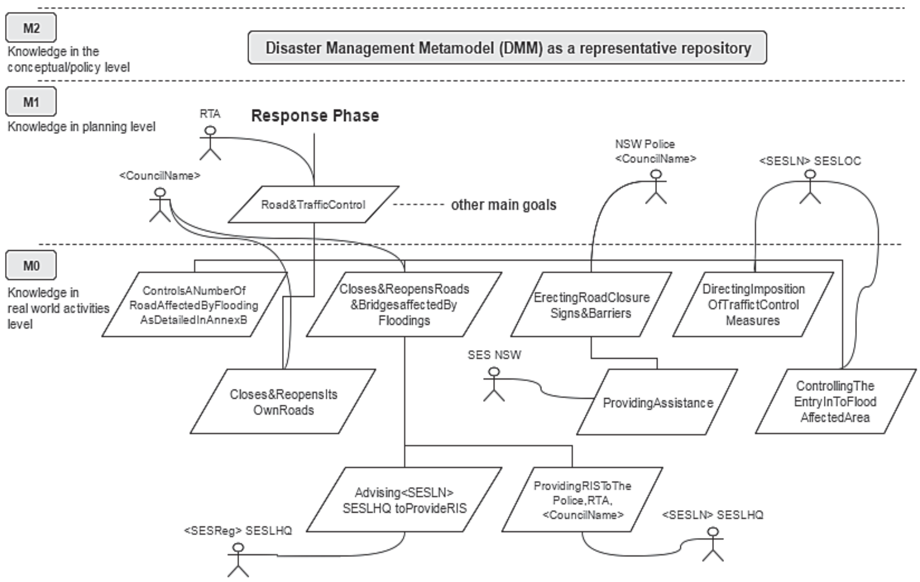


Figure 6.11. A customized *goal model* of the flood SES NSW DISPLAN for a main goal "*Road and Traffic Control*".

6.3.1.2 Customising the role model

The customized the flood DISPLAN knowledge template of the SES NSW with respect to the *role model* template results in the *role model* template as shown in Table 6.1. In the table, only one particular role *R7*: <*SES Local Name*> SES Local Operational Controller (<*SESLN*> SESLOC) is exhibited as an example. As this is a knowledge element class, this role is subject to change depending on where the template will be instantiated to. In this case, the <*SESLN*> will be modified following the municipality name. For instance, if the template instantiates the Wollongong flood DISPLAN knowledge then the role *R7* will be automatically adjusted to be the Wollongong SESLOC.

Table 6.1 A customized *role model* of the DISPLAN for a role "<*SESLN*> SESLOC".

DMM-based repository		*M2*
Role knowledge		**MOF layer**
Role ID	R7	*M1*
Role Name	<SESLN> SESLOC	
Description	If the knowledge analysed and modelled is from Wollongong area, then the <SESLN> becomes Wollongong SESLOC.	
Responsibility	1. Directing of the traffic control measures. 2. Controlling entry into flood affected areas.	*M0*
Constraint	In flood events, the <SESLN>SES Local Operations Controller may direct the imposition of traffic control measures. The entry into flood affected areas will be controlled in accordance with the provisions of the State Emergency Service Act, 1989 (Part 5, Sections 19, 20, 21 and 22) and the State Emergency Rescue Management Act, 1989 (Part 4, Sections 60KA, 60L and 61).	

The elements *responsibility* in this *role model* template are identified from the *goal model*. As can be seen in *goal model* at Figure 6.11, the role: *<SESLN> SESLOC* responsible for 2 (two) sub-goals: "*Directing of the traffic control measures*" and "*Controlling entry into flood affected areas*". In the *role model,* these two sub-goals from the *goal model* (Figure 6.11) are automatically structured as knowledge element *responsibility*, as shown in Table 6.1. For the element *constraint*, the knowledge engineer needs to revisit to SES NSW template to obtain this as it is not structured in the *goal model*.

The next step is determining whether each of the knowledge elements of the *role model* is placed as either *M0* or *M1*, following the MOF layer. As described in Table 6.1, a knowledge engineer determines that the elements *role name* and *description* are positioned as *M1*. This is because in this context, these elements are only about an agent playing the role "*<SESLN>*" SESLOC without any further description as to what that particular role is responsible for whereas, the elements *responsibility* and *constraint* are placed as *M0*. This is because essentially these two elements are the typical knowledge elements which the roles will embrace as guidance to perform in a real word activity.

6.3.1.3 Customising the organisation model

As in the *role model*, all the role knowledge elements of the *organisation model* are obtained from the *goal model* (in Figure 6.11). The customised *organisation model* is as outlined in Figure 6.12. As can be seen, as the SES NSW is the highest typical DM agency in the federal level in Australia, this means it *Controls* the one in the region/the lower administrative level (*<SESReg> SESRDHQ*>). Likewise, the one in the region level *Controls* the one in the city level (*<SESLN> SESLHQ*). As the *<CityCouncil>* represents an authoritative in the city level then it *isPeer* with *<SESLN> SESLHQ*.

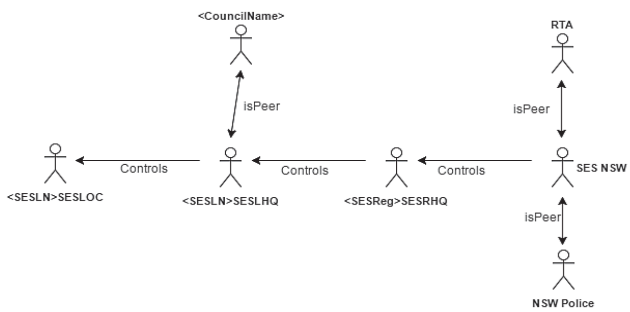


Figure 6.12 A customized *organisation model* of the flood SES NSW DISPLAN knowledge.

Similarly, RTA and NSW Police are the organisations in the federal level, therefore, each of them *isPeer* with SES NSW. Lastly, a knowledge engineer marks the element *role name* as *M1* as it only describes the name of the role and the element *description* as *M0* as it details the roles. This is as shown in Table 6.2.

Table 6.2 A customised *organisation model* structured in table with respect to MOF.

DMM-based repository					*M2*
Organisation knowledge					**MOF layer**
Role A		Organisation knowledge	Role B		*M1*
Role Name	<SESLN> SESLOC	*isControlledBy*	Role Name	<SESLN> SESLHQ	
Description	<SESLN> State Emergency Service Local Operational Controller		Description	<SESLN> State Emergency Service Local Headquarter	*M0*
Role Name	<SESLN> SESLHQ	*isControlledBy*	Role Name	<SESReg> SESRHQ	*M1*
Description	<SESLN> State Emergency Service Local Headquarter		Description	<SESReg> State Emergency Service Regional Headquarter	*M0*
…and so on					

6.3.1.4 Customising the interaction model

A in the customising *organisation model,* the knowledge elements of the *interaction model* are obtained from the *goal model*. The elements of the *interaction model* are described in Figure 6.13.

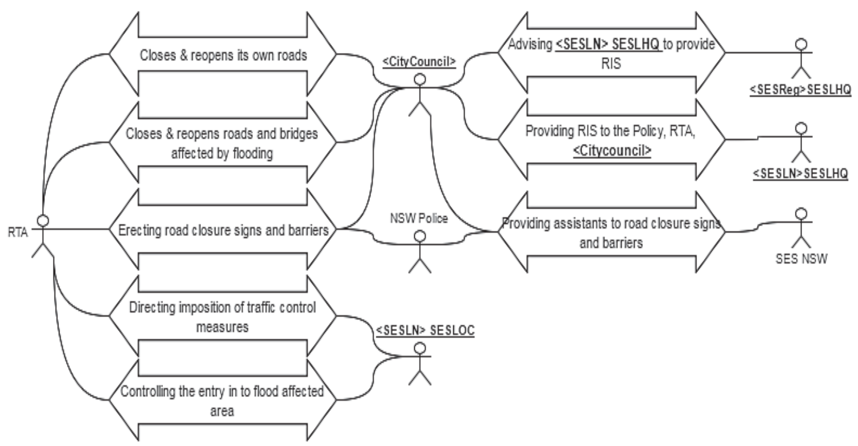


Figure 6.13 A customized *interaction model* of the flood SES NSW DISPLAN knowledge.

In customising the *interaction model*, only the *activity* with more than one role responsible for will be structured in the model. For instance, the *activity* "*Closes and reopens its own roads*" is structured in the *interaction model* in Figure 6.13 as in the *goal model* it is pursued by two roles, namely: <*CityCouncil*> and RTA (See Figure 6.11). In other words, the activities that are pursued by only one role will not be structured in the *interaction model*. Another example is "*Advising*

<SESLN> SESLHQ (SES Local Heaquarter) to provide RIS (Road Information Safety)". This activity is a sub-goal identified from the *goal model*. Thus, it is automatically structured in the *interaction model* as it is pursued by more than one role, namely *<CityCouncil>* and *<SESReg> SESRHQ* (SES Regional Headquarter). A knowledge engineer continues to complete knowledge elements in the *interaction model* as shown in Figure 6.13. Once the *interaction model* is fully customised, a knowledge engineer marks whether the element in the model is either *M0* or *M1*, as illustrated in Table 6.3.

Table 6.3 A customised *interaction model* structured in table with respect to MOF.

DMM-based repository			*M2*
Interaction knowledge			**MOF layer**
Role A	*rolePursueGoal*	Role B	
RTA	Closes and Reopens its own roads	*<CouncilName>*	*M1*
Road and Traffic Authority	The council closes and re-opens its own roads that is initiated by RTA	Name of the city council where the activity is taken place.	*M0*
NSW Police	Erecting road closure signs and barriers	*<CouncilName>*	*M1*
New South Wales Police	When resources permit, the SES assists Council or the Police by erecting road closure signs and barriers	Name of the city council where the activity is taken place.	*M0*
…and so on			

For instance, RTA and *<CouncilName>* are interacted for the goal: "*Closes and Reopens its own roads*". According to the MOF framework, this knowledge element is placed as *M1* as it represents the policy/planning level while the detail description of it is positioned as *M0* as it represents the knowledge in the real activity layer to be embraced by the stakeholders directly. The process produces the customized *interaction model* shown in Figure 6.13.

6.3.1.5 Customising the environment model

This customizing process of the *environment model* produces a customized *environment model* template based on the flood DISPLAN knowledge template of the SES NSW, as shown in Table 6.4. For customising the *environment model*, a knowledge engineer needs to revisit the flood DISPLAN of the SES NSW template as the typical knowledge elements in this model is not structured yet in any of previous customised models (*goal, role, organisation* and *interaction models*) except for the element *role involved*. For instance, in Table 6.4, an environment knowledge "*List of roads and bridges affected by flooding*" is identified. As this typical knowledge element is about *roads* and *bridges* then there should be specific addresses for these. These elements then lay down in element *attribute*. The element *roles involved* in the *environment model* is then identified from the *role model*. Customising the *environment model* identifies that there are 5 (five) roles utilising this environment knowledge element to complete their tasks, namely NSW Police, <*CityCouncil*>, RTA, <*SESLN*> *SESLOC* and <*SESReg*> *SESRHQ*.

Table 6.4. The customized *environment model* of the flood SES NSW DISPLAN knowledge.

DMM-based repository			M2
Environment knowledge			**MOF layer**
Environment Entity ID	E1		M1
Environment Name	List of roads and bridges affected by flooding		
Description	List of roads and bridges affected by flooding used by the roles to achieve the goal.		
Attributes	#	Unique number distinguishing inputted data	M0
	Type	Road/Bridge	
	Address	The address/geo location	
Roles Involved	NSW Police		
	<CouncilName>		
	RTA		
	<SESLN> SESLOC		
	<SESReg> SESRHQ		

Once it is completely analysed, the knowledge engineer identifies which of the knowledge elements will be marked as either *M0* or *M1* following the MOF framework. As described in the table, the knowledge elements: *environment entitiy ID, environment name* and *description* are designated as *M1* as, in this context, they represent the knowledge in the planning level, while the element *attributes* and *roles involved* are marked as *M0* as essentially these knowledge elements represent the knowledge in the real world activities.

6.3.1.6 Customising the agent model

This process results in a customized *agent model* as shown in Table 6.5. The knowledge elements in the *agent model* are obtained from other customised models except for the element *trigger* as it is not identified yet in any previous customised models. The element *agent name* and *role played*: <*SESLN*> *SESLOC*, initially are identified from the *goal model*. The element *activity name*: "*Road and traffic controller*" is essentially the main goal therefore it is also identified from the *goal model* (See Figure 6.11). The two elements of *action*: "*Directing the imposition of traffic control measures*" and "*Controlling the entry into flood affected areas*" are essential the sub-goals where the agent (plays the role) responsible for. These two elements are identified from the *goal model* as they are the same elements of sub-goals in the *goal model* (Figure 6.11). At the same time, the element *activity name*: "*Road and Traffic Control*" is also identified at once as it is fundamentally the main goal in the *goal model*. For the element *trigger*, the knowledge engineer needs to revisit the flood DISPLAN template of the SES NSW to arrange it. There are 3 (three) element *triggers* being identified. This means, whenever any of these *triggers* occurs, agent (plays the role) initiates the element *functionality*: "*Road and traffic Control*".

Table 6.5. The customized *agent model* of the flood SES NSW DISPLAN knowledge.

DMM-based repository			M2
Agent knowledge			**MOF layer**
Agent ID	A1		M1
Agent name	Name <SESLN> SESLOC		
Role played	<SESLN> SESLOC		
Activity	Activity Name:	<SESLN> SESLOC controls Road and Traffic	M0
	Functionality:	Road and Traffic Control	
	Trigger:	▪ On the receipt of a Bureau of Meteorology Preliminary Flood Warning, Flood Warning, Flood Watch, Severe Thunderstorm Warning or a Severe Weather Warning for flash flooding. ▪ On the receipt of a dam failure alert. ▪ When other evidences lead to an expectation of flooding within the council area.	
	Action:	1. Directing the imposition of traffic control measures. 2. Controlling the entry into flood affected areas.	
Environment Entity	E1		

As for the element *environment entity*, it is identified from the *environment model* by observing the element *roles involved*. As can be seen from the *environment model* in Table 6.4, the element *agent name*: *<SESLN> SESLOC* is included in the element *role involved* in that *model*. Therefore, the element *environment entity ID* is automatically inserted in this *agent model*.

Once they are all structured in the *agent model* template, subsequently the knowledge engineer identifies each of the knowledge elements as either *M0* or *M1*, with respect to the MOF framework. As in Table 6.5, the knowledge elements *agent name* and *role played* are placed as *M1* as they only inform the name of the agent whereas the elements *activity* and *environment entity* are positioned as *M0*.

6.3.1.7 Customising the scenario model

The customizing process of the *scenario model* results in a customized *scenario model* as drawn in Table 6.6. As in the *agent model*, all the knowledge elements in the *scenario model* are identified from the previous customised models except for the elements *pre-, post-condition* and *condition* per se.

Customising the *scenario model* begins by identifying the element *name* which is also an element *goal* in the *scenario model*. It is essentially a main goal "*Road and Traffic Control*" that is identified from the *goal model*. Thus, the element *initiator* is the same as the one in the *goal model*. As this main goal in the *scenario model* is the same as the one in the *agent model* (See Table 6.5), the element *trigger* in this model will automatically be referred to the one in the *agent model*. The three elements of *trigger* from the *agent model* are then structured in the *scenario* *model*. For the element *pre-condition*, the knowledge engineer revisits the flood DISPLAN template of the SES NSW to identify it. It is the condition after the *trigger* but before performing the *activity* whereas the *post-condition* is the condition after all the activities have been accomplished. The element *pre-condition* being identified from the DISPLAN template is "*Road Information Service has passed to NSW Police, RTA and <CouncilName>, Local Emergency Service, Public and <SESReg>SESRHQ*" and the element *post-condition* is "*Road and traffic are under control*".

Table 6.6. The customized *scenario model* of the flood SES NSW DISPLAN knowledge.

DMM-based repository					M2
Scenario knowledge					**MOF layer**
Scenario	S1				M1
Name	Road and Traffic Control scenario				
Goal	Road and Traffic Control				
Initiator	Road and Traffic Authority (RTA)				
Trigger	▪ On the receipt of a Bureau of Meteorology Preliminary Flood Warning, Flood Warning, Flood Watch, Severe Thunderstorm Warning or a Severe Weather Warning for flash flooding. ▪ On the receipt of a dam failure alert. ▪ When other evidences lead to an expectation of flooding within the council area.				M0
Pre-condition	Road Information Service has passed to NSW Police, RTA and **<CouncilName>,** Local Emergency Service, Public and **<SESReg> SESRHQ**.				
Post-condition	Road and traffic are under control.				
Description	Road and Traffic Control is a control activity of a number of roads within the council area affected by flooding. Details are provided in Annex B.				
Condition	Step	Activity	Role	Environment Entity	
Sequential	1	Controls **a number of roads** within the council area that are affected by flooding as detailed in Annex B	R1		
	2	Closes and reopens its **own roads**	R1, R2	E1	
	3	Closes and re-opens **roads and bridges affected** by flooding	R1, R2, R3, R4	E1	
	3.1	Advising **<SESLN> SESLHQ** to provide a Road Information Service (RIS)	R1, R2, R3	E1	
	3.2	Providing RIS to the Police, RTA and **<CouncilName>**	R1, R2, R3, R5	E2	
	4	Erecting **road closure signs and barriers**	R1, R3, R3	E1	
	4.1	Provides assistance for Erecting **road closure signs and barriers**	R1, R6	E2	
	5	Directing the imposition of traffic control measures	R1, R7	E1	
	6	Controlling the entry into **flood-affected areas**	R1, R7	E1	

All the knowledge elements of *activity* are the sub-goals of the main goal "*Road and Traffic Control*" in the *goal model* (See Figure 6.11). The element *role* is the role(s) that is/are involved in each of the sub-goal and identified also from the *goal model*. The element *environment entity* is identified from the *environment model*. Whenever a role is involved in the *environment model* that particular role will be automatically structure in the element *environment entity* in the *scenario model*. For instance, in Table 6.6, an *activity* “*closes and reopens its own roads*” has 2 (two) roles involved, namely: *R1* and *R2*, and an element *environment entity E1*. The two roles are identified from the *goal model,* namely: RTA and <*CityCouncil*>. The detail of these two roles *R1* and *R2* are referred to the *role models* (for the detail of *R1* is as in the Table 6.1 and *R2* is included in Appendix D). The detail of *E1* is referred to Table 6.4 the *environment model*. The complete *scenario model* for the main goal “*Road and Traffic Control*” is shown in Table 6.6.

Once all the knowledge elements are identified, subsequently the knowledge engineer designates whether each element is positioned as *M0* or *M1* following the MOF framework representing the knowledge in the planning/policy level or real world activity. As illustrated in Table 6.6, the elements *goal* and the *initiator* are marked as *M1* as they both only show the objective that needs to be accomplished in this scenario and the roles responsible. Other elements in the model are designated as *M0* as they are, fundamentally, the knowledge elements describing the real world activities.

6.3.2 Stage 2: Generating Agent-Based Model DISPLANs

Each of the customized ABMs DISPLAN knowledge templates is ready to instantiate any particular ABM plan based on the local wisdom where it will be implemented to. All NSW regions and their municipalities can adopt the same DISPLAN knowledge template to produce each of their local DISPLANs (local flood plans). The template is used to instantiate local plans efficiently that share the various commonalities of knowledge across all areas within NSW with adjustable local context. Within the state of NSW, there are 141 municipalities within 18 regions (SES NSW Australia, 2016). Thus, the ABM customised templates apply to all 141 municipalities. In this case study, the Wollongong Municipality is employed as an exemplar. This instance conforms and inherits all the commonalities of knowledge element classes of the ABM templates adaptable based on the local characteristics of Wollongong. The details of all models generates are included in Appendix D in this thesis. The generation (modelling) process is illustrated for each model type in what follows in this section.

6.3.2.1 Generating the goal model

The *goal model* of Wollongong SES flood DISPLAN fundamentally represents the same knowledge as its class (customized *goal model* as in the Figure 6.11), but in the context of the Wollongong Municipality. The knowledge engineer substitutes all the knowledge element classes from the customized version with the one representing the Wollongong characteristics, accordingly. This then becomes the *goal model* of Wollongong flood DISPLAN knowledge as drawn in Figure 6.14.

Some of the knowledge elements are substituted to represent the characteristics of the Wollongong City whereas others generic ones remain applicable. In Table 6.7, the substitution process is shown. All the knowledge elements in the bracket “< >” are substituted with the ones represented the knowledge of the Wollongong Municipality. A knowledge engineer goes through all the knowledge element classes of the customised *goal model* to generate the instance one. Once it is in place then it is ready to be transferred into the repository.

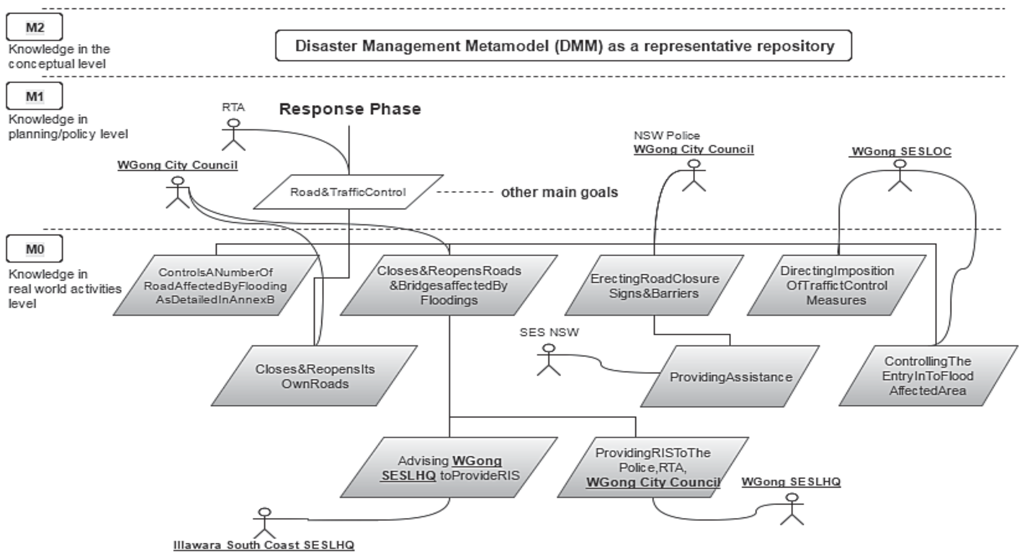


Figure 6.14 The *goal model* of Wollongong flood DISPLAN knowledge.

Table 6.7 Generating process of knowledge element instances from the *goal model* DISPLAN knowledge of Wollongong Municipality.

DISPLAN Knowledge template	Wollongong City DISPLAN instance
The ~~<SESLN>~~ **SES Local Operations Controller** may direct the imposition of traffic control measures	<SESLN> = SES Local Name = Wollongong City SES Local Operations Controller
~~<SESLN>~~ **SES Local Headquarter** provides Road Information Service (RIS) to the Police, RTA and the ~~<CouncilName>~~	<CouncilName> = Wollongong City Council
Controls a number of ~~<roads>~~ within the ~~<council area>~~ that are affected by flooding as detailed in annex B	Roads of Wollongong City: Princess Highway at Kembla grange; West Dapto Road at Dapto Creek and junction at Sheaffes Road; Cordeaux Road, Figtree; Princes Hwy, Unanderra (between Cordeaux Rd & Farmborough Rd); Bellambi St, Tarrawanna (Southern End), etc; Council area of Wollongong City: Austinmer, Coledale, Thirroul, Bulli, Corrimal, Woonona, etc.
~~<SESReg>~~ **SESRHQ**	<SESReg> = SES Regional = Illawara South Coast SES Local Headquarter
~~<SESLN>~~ **SESLHQ**	<SESLN> = SES Local Name = Wollongong City SES Local Headquarter
…and so on	

6.3.2.2 Generating the role model

As in the *goal model*, generating the *role model* in this case study is to instantiate the *role model* of Wollongong flood DISPLAN knowledge from the customized one (the customised *role model* as in Table 6.1). This is as shown in Table 6.8. As can be seen, all the knowledge element classes of the customized one are substituted with the typical knowledge but associated with the Wollongong City. In the table, for instance, the element class *role <SESLN> SES LOC* (Local Operational Controller) is substituted with the SES Local Name of Wollongong to be role of *Wollongong SESLOC*. This substitution is also applied in other elements in the *role model*, for instance in the element *description* and *constraint*.

Table 6.8 The *role model* of Wollongong flood DISPLAN knowledge.

DMM-based repository		*M2*
Role knowledge		**MOF layer**
Role ID	R7	*M1*
Role Name	<SESLN> **Wollongong City** SESLOC	
Description	SES Local Operational Controller (SESLOC) of the **Wollongong City**	
Responsibility	Directing the imposition of the traffic control measures. Controlling the entry into flood affected areas.	*M0*
Constraint	In flood events, the ~~**<SESLN>**~~ **Wollongong City** SES Local Operations Controller may direct the imposition of traffic control measures. The entry into flood affected areas will be controlled in accordance with the provisions of the State Emergency Service Act, 1989 (Part 5, Sections 19, 20, 21 and 22) and the State Emergency Rescue Management Act, 1989 (Part 4, Sections 60KA, 60L and 61).	

6.3.2.3 Generating the organisation model

As in the previous models, generating the *organisation model* in this case study is to generate an *organisation model* of Wollongong flood DISPLAN knowledge out of the customized one (Figure 6.12). This is as shown in Figure 6.15.

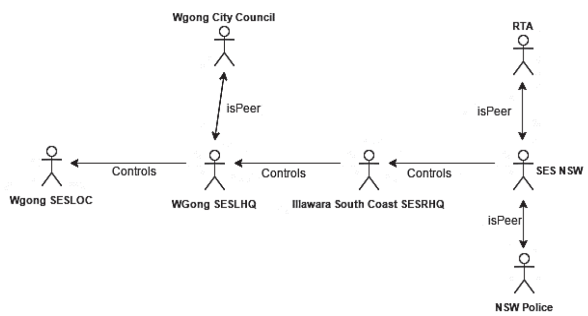


Figure 6.15 The *organisation model* of Wollongong flood DISPLAN knowledge.

All the knowledge element classes of roles in the customised *organisation model* are substituted with the ones representing the Wollongong characteristics. For instance, the roles containing <*SESLN*> will be changed with Wollongong as SESLN means SES Local Name, e.q.

<*SESLN*> *SESLOC* → Wollongong SESLOC, <*SESLN*> *SESLHQ* → Wollongong SESLHQ, etc. The <*CityName*> will be replaced by the name of the city, that is Wollongong City and the <*SESReg*> will be replaced with the Illawarra South Coast as this is the region where Wollongong City is situated. On the other hand, the NSW police, SES and RTA remains the same as they are, regardless of the area. The relationship types as well as the knowledge layers based on MOF framework remain the same as in the customised version.

6.3.2.4 Generating the interaction model

This process is aimed to generate an *interaction model* of Wollongong flood DISPLAN knowledge out of the customized one (as in Figure 6.13). The resultant of the process is as shown in Figure 6.16. The substitution processes are the same as in the other previous models.

The local and region names classes will be replaced with instance ones representing the city and region where they are. In this example, they are Wollongong City and Illawarra South Coast region respectively. All other elements are unchanged, for instance, the element role RTA, NSW Policy and SES NSW. As for the knowledge elements the *rolePursueGoals,* they will automatically follow the characteristics of the Wollongong City. Once this model is completed, it then becomes ready to be transferred into the repository.

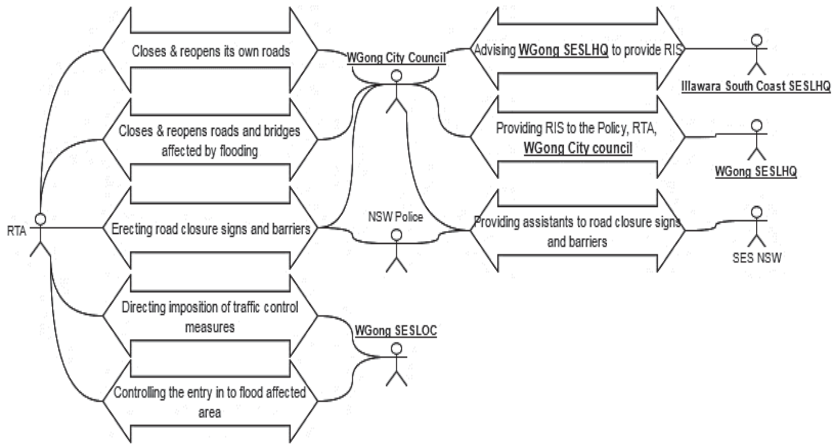


Figure 6.16 The *interaction model* of Wollongong flood DISPLAN knowledge.

6.3.2.5 Generating the environment model

This process is aimed to generate the *environment model* of Wollongong flood DISPLAN knowledge out of the customized one, as shown in Table 6.9. An example portrayed in the model is the "*List of the roads and bridges affected by flooding*". As this is the *environment model* of Wollongong DISPLAN, this means that the elements *roads* and *bridges* that need to be taken into account represent those in the area of Wollongong City. To be able to be informed where the roads and *bridges* in the Wollongong City are is detailed in the element *attributes*. For instance for the element *roads*, one of the instances is “*Prince Highway at Kembla grange*” and for the element *bridges*, one of the instances is “*Collins creek bridge*”. For the element *roles involved*, all the knowledge element classes are substituted to the once representing the Wollongong city as in the previous generating processes. Once this process is completed, it is made ready to be transferred into the repository.

Table 6.9 The *environment model* of the Wollongong flood DISPLAN knowledge.

DMM-based repository			*M2*
Environment knowledge			**MOF layer**
Environment Entity ID	E1		*M1*
Environment Name	List of roads and bridges affected by flooding		
Description	List of roads and bridges affected by flooding used by the roles to achieve the goal.		
Attributes	#	1	*M0*
	Type	Road	
	Address	Princess Highway at Kembla grange	
	#	2	
	Type	Road	
	Address	West Dapto Road at Dapto Creek and junction at Sheaffes Road;	
	#	4	
	Type	Bridge	
	Address	Mullet Creek bridge	
	#	5	
	Type	Bridge	
	Address	Collins creek bridge	
		….and so on	
Roles Involved	NSW Police		
	~~<CouncilName>~~ **Wollongong City Council**		
	RTA		
	~~<SESLN>~~ **Wollongong City** SESLOC		
	~~<SESReg>~~ **Illawara South Coast** SESRHQ		

6.3.2.6 Generating the agent model

The *agent model* of Wollongong flood DISPLAN knowledge is generated from the customised *agent model* (as in Table 6.5). This is shown in Table 6.10. As can be seen in the table, the knowledge element classes, for instance <*SESLN*> are substituted with the Wollongong City. A knowledge engineer goes through all the knowledge elements classes in the customized template under scrutiny to substitute them with the Wollongong characteristics. Once this process is completed, it is ready to be transferred into the repository.

Table 6.10 The *agent model* of the Wollongong flood DISPLAN knowledge.

DMM-based repository			*M2*
Agent knowledge			**MOF layer**
Agent ID	A1		*M1*
Agent name	Name ~~<SESLN>~~ **Wollongong City** SESLOC		
Role played	~~<SESLN>~~ **Wollongong City** SESLOC		
Activity	Activity Name:	~~<SESLN>~~ **Wollongong City** SESLOC controls Road and Traffic	*M0*
	Functionality:	Road and Traffic Control	
	Trigger:	▪ On the receipt of a Bureau of Meteorology Preliminary Flood Warning, Flood Warning, Flood Watch, Severe Thunderstorm Warning or a Severe Weather Warning for flash flooding. ▪ On the receipt of a dam failure alert. ▪ When other evidences lead to an expectation of flooding within the council area.	
	Action:	1. Directing the imposition of traffic control measures. 2. Controlling the entry into flood affected areas.	
Environment Entity	E1 = List of roads and bridges affected by flooding		

6.3.2.7 Generating the scenario model

Generating the *scenario model* produces a *scenario model* of Wollongong flood DISPLAN knowledge. This is shown in Table 6.11. All the knowledge element classes are substituted with ones representing the Wollongong Municipality. For instance, in the element *pro-condition*, the knowledge classes <*CouncilName*> and <*SESReg*> are substituted with Wollongong City and Illawara South Coast respectively. Another example is the element *activity* "*closes and reopens roads and bridges affected by flooding*". The element roles responsible for this *activity* are *R1 and R2*. The detail of these roles is referred to the *role models*. In the *activity*, the elements *roads* and *bridges* are automatically refer to *environment entity*. In this example they refer to *E1*.

A knowledge engineer goes through the customised *scenario model* to examine and substitute all the knowledge element classes accordingly to produce the Wollongong flood DISPLAN knowledge. Once this process is completed, it then is ready to be transferred into the repository. In the section that follows, the knowledge transfers of the generated ABMs of Wollongong flood DISPLAN knowledge from the Stage 2 are illustrated.

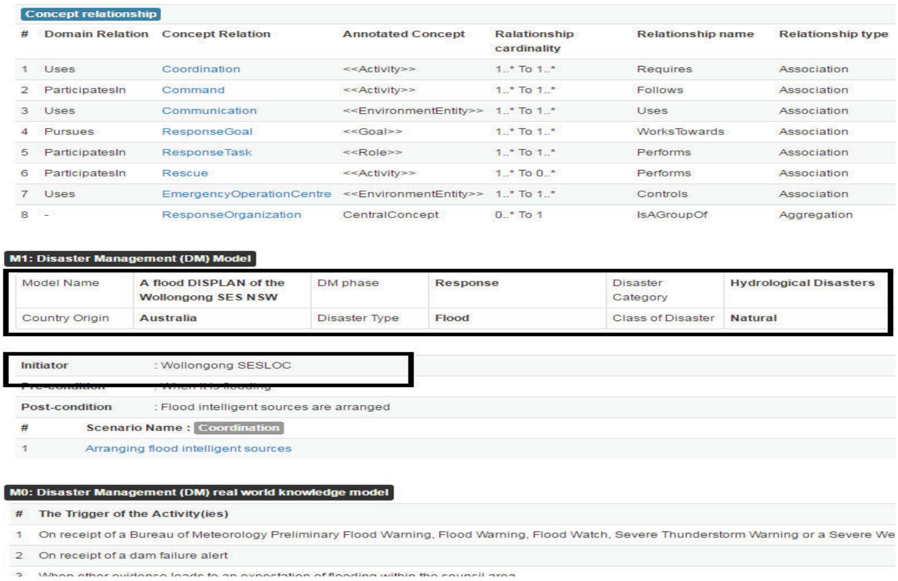
Table 6.11 The *scenario model* of the Wollongong flood DISPLAN knowledge

DMM-based repository					*M2*
Scenario knowledge					**MOF layer**
Scenario	S1				*M1*
Name	Road and Traffic Control scenario				
Goal	Road and Traffic Control				
Initiator	Road and Traffic Authority (RTA)				
Trigger	▪ On the receipt of a Bureau of Meteorology Preliminary Flood Warning, Flood Warning, Flood Watch, Severe Thunderstorm Warning or a Severe Weather Warning for flash flooding. ▪ On the receipt of a dam failure alert. ▪ When other evidences lead to an expectation of flooding within the council area.				*M0*
Pre-condition	Road Information Service has passed to NSW Police, RTA and **~~<CouncilName>~~ Wollongong City council**, Local Emergency Service, Public and **~~<SESReg>~~ Illawara South Coast** SESRHQ.				
Post-condition	Road and traffic are under control.				
Description	Road and Traffic Control is a control activity of a number of roads within the council area affected by flooding. Details are provided in Annex B.				
Condition	*Step*	*Activity*	*Role*	*Environment Entity*	
Sequential	1	Controls **a number of roads** within the council area that are affected by flooding as detailed in Annex B	R1		
	2	Closes and reopens **its own roads**	R1, R2	E1	
	3	Closes and re-opens **roads and bridges affected** by flooding	R1, R2, R3, R4	E2	
	3.1	Advising **~~<SESLN>~~ Wollongong City SESLHQ** to provide a Road Information Service (RIS)	R1, R2, R3	E1	
	3.2	Providing RIS to the Police, RTA and **~~<CouncilName>~~ Wollongong City Council**	R1, R2, R3, R5	E1	
	4	Erecting **road closure signs and barriers**	R1, R3, R3	E1	
	4.1	Provides assistance for Erecting **road closure signs and barriers**	R1, R6	E1	
	5	Directing the imposition of traffic control measures	R1, R7	E1	
	6	Controlling the entry into **flood-affected areas**	R1, R7	E1	

6.3.3 Stage 3: Knowledge transfer

The knowledge transfer stage of the framework remains the same. That is, in this case study this stage is similar as was presented in Chapter 5. There are two activities in this stage, namely: 1) annotating the DMM to prepare the repository for the depositing process; and 2) the knowledge transfer process itself. The annotated DMM concepts are unchanged thus the annotating process itself remains the same as in Chapter 5. The plan transferred into the repository here is the

Wollongong DISPLAN. Figure 6.17 shows the Wollongong flood DISPLAN knowledge structured in the repository. However unlike Chapter 5, a post-evaluation of the actual knowledge transferred is undertaken here. This will in essence ascertain that the Wollongong flood DISPLAN knowledge structured in the DMM-based repository reflects original DISPLAN. This post-evaluation is conducted by a DM expert from the SES NSW agency for this purpose. This is discussed in the following section.



Concept relationship

#	Domain Relation	Concept Relation	Annotated Concept	Ralationship cardinality	Relationship name	Relationship type
1	Uses	Coordination	<<Activity>>	1..* To 1..*	Requires	Association
2	ParticipatesIn	Command	<<Activity>>	1..* To 1..*	Follows	Association
3	Uses	Communication	<<EnvironmentEntity>>	1..* To 1..*	Uses	Association
4	Pursues	ResponseGoal	<<Goal>>	1..* To 1..*	WorksTowards	Association
5	ParticipatesIn	ResponseTask	<<Role>>	1..* To 1..*	Performs	Association
6	ParticipatesIn	Rescue	<<Activity>>	1..* To 0..*	Performs	Association
7	Uses	EmergencyOperationCentre	<<EnvironmentEntity>>	1..* To 1..*	Controls	Association
8	-	ResponseOrganization	CentralConcept	0..* To 1	IsAGroupOf	Aggregation

M1: Disaster Management (DM) Model

Model Name	**A flood DISPLAN of the Wollongong SES NSW**	DM phase	**Response**	Disaster Category	**Hydrological Disasters**
Country Origin	**Australia**	Disaster Type	**Flood**	Class of Disaster	**Natural**

Initiator : Wollongong SESLOC

Post-condition : Flood intelligent sources are arranged

#	Scenario Name : Coordination
1	Arranging flood intelligent sources

M0: Disaster Management (DM) real world knowledge model

#	The Trigger of the Activity(ies)
1	On receipt of a Bureau of Meteorology Preliminary Flood Warning, Flood Warning, Flood Watch, Severe Thunderstorm Warning or a Severe We
2	On receipt of a dam failure alert

Figure 6.17 The Wollongong flood DISPLAN knowledge structure in the repository.

6.4 Post-evaluation of the resultant knowledge

In the previous chapter, an initial evaluation was undertaken with the Wagga-Wagga SES NSW DISPLAN as a real case study from the DM agency. That evaluation illustrated successfully the conversion process from the Wagga-Wagga DISPLAN to the repository and as earlier discussed the evaluation highlighted opportunities to improve the efficiency of the framework in two ways: 1) Utilising a template DISPLAN instead of unique plan to effectively develop other plans; 2) Employing depth-first approach in increasing the effectivity in the generating process of other DISPLANs. In this chapter, these improvements were evaluated using the Wollongong Municipality Flood Management plans (part of NSW SES).

Comparing the first evaluation with this second one, the use of template reduces the number of revisits of the DISPLAN by the modellers. The number of document revisits is reduced by at least 4 (four) times: they are in revisiting the *role model, environment* model*, agent model and scenario model* for acquiring the constraint elements, environment entity elements, trigger elements and pre- and post- condition and condition per se respectively (other knowledge elements in these four models are acquired from the *goal model*. This is as elucidated in Chapter

4). For instance, in analysis and modelling the *role model*, the knowledge engineer acquired the elements of roles and their responsibilities from the *goal model* while the constraint elements are from revisiting the DISPLAN again. If the DISPLAN constitutes a long and thick document to be analysed and modelled, these tasks will be significantly costlier. The evaluation of the second case study experienced this benefit. However, as mentioned explicitly in first paragraph of Section 6.2.2 line 6: "*but this possibility is not pursued in this thesis*", this research will not pursue the validation process of depth-first approach instead the focus of it is to develop a knowledge analysis framework. This can definitely be a future research direction.

The next concern is to ascertain the knowledge elements that are deposited in the repository are of benefit for the target user groups, i.e. the DM stakeholders. This post-evaluation process aims at getting feedback of a DM expert about this. This is important to ascertain that the new knowledge representation in the DMM-based repository is faithful to the DISPLAN and reusable by the authoritative agency for a comprehensive and holistic decision-making mechanism. A DM expert from the State Emergency Services (SES) of NSW, with intimate knowledge of the scope of the DISPLAN converted, is engaged in this evaluation. The involvement of the DM expert aims to ensure that the knowledge elements from the DISPLAN are fully extracted and deposited into the DMM-based repository without losing any meaning. This post-evaluation is performed by employing description and observational approach based on DSR evaluation framework of Venable *et al.* (2016) to evaluate the value of the developed framework to the DM stakeholders as the target user groups (the questions for the evaluation are included as Appendix B).

It is wort noting that as the post evaluation is conducted to ascertain the specific criteria as the framework is enhanced (as shown in Table 6.12), the expert from the SES NSW State with the intimate DM flood knowledge is employed to measure the resultant of the process. The expert review is utilised with the aim to represent the view of the wider spectrum of the stakeholders. However, for the detail interpretation of the DM concepts used, the involvement of as a wider variety of the stakeholders as possible directly is worth for the future research direction.

The post-evaluation being conducted by the DM expert from the SES NSW begins by examining whether the resultant knowledge items and the way they relate to each other in the repository remain the same as in the original DISPLAN. This is the first and foremost criteria that need to be thoroughly examined from the evaluation as the consequence will determine the degree of usability and benefit of the resultant knowledge in the repository for the DM stakeholders. The response from the expert conducting the evaluation is positive as he states "*The process accurately models knowledge contained in the SES DISPLANs*". It is worth noting that in conducting this post-evaluation, the prototype being developed for this research is utilised. The prototype allows the DM expert to easily access and browse the knowledge elements structured in the repository by ‘clicking’ them.

Table 6.12. Evaluation outcome of benefits and usability of the deposited knowledge from the DM expert of the SES NSW State.

Addressing criteria	**Outcome**	**Expert’s comment**
Knowledge in the repository is unchanged from its original	Y	“The process accurately models knowledge contained in the SES DISPLANs”.
The use of DISPLAN knowledge template instead of a unique plan increases the efficiency in disseminating and developing other plans.	Y	“Knowledge that is modelled from the SES DISPLAN can be instantiated into disaster plans for other areas while maintaining accuracy of the context”
New knowledge representation in the repository is comprehended more effective and efficient.	Y	“This presents opportunities to improve the conceptual completeness of the disaster management by organisations”.
Incomplete knowledge can be identified systematically	Y	“By developing the DMM and using ABM, gaps where actions or tasks have not been planned for can be elicited”.
The new knowledge representation can help DM stakeholders in a better decision-support system mechanism.	Y	“The system, enables better access, sharing and maintenance of knowledge”.
New knowledge structure in the repository can help DM stakeholder in identifying appropriate response in any point of the disaster timeline.	Y	“Each agent in can understand each of their role based on the urgency in the DM timeline comprehensively and holistically”.
Overall, the framework can be used in DM resilience agenda	Y	“The framework enhances the use of standalone DISPLAN by making knowledge more accessible, more searchable, and assisting in developing comprehensive (semantically and ABM complete) arrangements supporting effective decision making. Important elements of a resilient community is that it promotes sharing of knowledge, proactive decision making and is planned. The framework supports the achievement of these and other resilience indicators”.

The post-evaluation ascertains that the knowledge transferred into the repository is faithful to the content of the DISPLAN of Wollongong Municipality. This in the process confirms that the enhanced framework which now utilises the template as a starting point, is not only more efficient but also effective. Subsequently, the local characteristics can then be effectively synchronised to the template to produce a complete particular DISPLAN. The response from the expert is positive as he states “*Knowledge that is modelled from the SES DISPLAN can be instantiated into disaster plans for other areas while maintaining accuracy of the context*”. This post-evaluation then continues looking at other criteria: 1). Whether the knowledge structured in the repository can be easily comprehended; 2). Whether it is comprehensive; 3). Whether the repository structure allows incompleteness of knowledge to be identified easily, and finally whether the developed framework contributes to furthering the DM resilience agenda for NSW Government.

The last criteria aims to obtain the respond from the expert whether the framework facilitates other stakeholders to reuse the best practice knowledge effectively and efficiently in other DM activities for the similar disaster. The expert reemphasises this by stating that this framework "*The framework enhances the use of standalone DISPLAN by making knowledge more accessible, more searchable, and assisting in developing comprehensive (semantically and ABM complete) arrangements supporting effective decision making. Important elements of a resilient community is that it promotes sharing of knowledge, proactive decision making and is planned. The framework supports the achievement of these and other resilience indicators*". The detail of the post-evaluation is as presented in Table 6.12.

6.5 Conclusion and Discussion utilising the SES NSW Template Case Study

The enhanced framework incorporates improvement opportunities identified from the first evaluation in Chapter 5. The framework is made more efficient. This evaluation successfully shows that, instead of utilizing a particular local DISPLAN, using a knowledge template as an input improves efficiency of the framework. The case study shows how the customised ABMs from the template of the SES NSW can instantiate ABMs from the Wollongong SES NSW DISPLAN. These customised ABMs can also be used develop ABMs for DISPLANs to other cities under the same jurisdiction easily. The evaluation also show that the depth-first approach contributes in improving the analysis and modelling activities of the ABMs. This approach also enables multiple modellers to be involved in the analysis and modelling concurrently. The process is potentially more effective as the approach guides the modellers not only '*where to*' start but '*how to*' perform the analysis. This approach also has the added benefit of preventing the inconsistency of the knowledge elements across the closely-correspondent models.

A post-evaluation is also conducted to ensure that all the improvements taken place in this evaluation do not change knowledge structure and meaning in the repository. A DM expert from the SES NSW, the agency where the case study come from, performs to evaluation. The post-evaluation shows the analysis and modelling process improves while the knowledge meaning and structure remains the same. To the end of this post-evaluation, this framework might contribute to the DM resilient agenda by increasing the awareness of the level of risk and resilience of the communities.

The second evaluation also presents a new and further opportunity to improve the efficiency of the process, particular in knowledge extraction stage. It is observed that, while *agent model* and *scenario model* are aimed to represent different points of views, in term of portraying the knowledge elements, both denote the same representation. Unlike others, both models present a main objective as a cornerstone to initiate the activities. The knowledge elements of both models are the same although one *agent model* describes the activities only for one particular agent whereas the *scenario model* integrates all the knowledge elements, including all the agents (playing roles in those activities) in one model. Table 6.10 and Table 6.11 of *agent model* and *scenario model* respectively illustrate the ABMs of the SES Wollongong Municipality DISPLAN for one identified main goal namely "*Road and Traffic Control*". Both models, in a case of any of the identified triggers occurs, drive all the agents to perform all the specified activities in order to pursue that main goal. From the *agent model*'s perspective, all activities in element *action* in the model is described for one agent only: Wollongong SES LOC. Thus, to be able to recognise all the agents who are performing activities to achieve the main goal "*Road and Traffic Control*", the stakeholders have to access and browse all the *agent models* who have the same main goal to identify them. This is due to the knowledge element structure in the *agent model* that shows only one agent for each *agent model* (pursuing one particular main goal). Thus, instead of seven ABMs, six of them (excluding *agent model*) is sufficient. Keeping the *scenario model* is favoured as it is more elaborate and has more knowledge elements. Nonetheless, this will be evaluated in yet another validation in Chapter 7. More importantly, this forthcoming evaluation will be applied to another state in Australia, in Victoria, to ascertain that the use of another template (that of Victoria) is just as feasible.

Finally, the post-evaluation by the DM expert shows that some knowledge elements in the repository can be fully comprehended as they contain specific elements, particular for people on the ground. Most knowledge elements are prescriptive and can be immediately utilized in a flood DM context. For some elements however, they need to be further specified with local characteristics to become sufficiently prescriptive towards enacting real world activities. An example of such an activity is the generation of flood evacuation warning. To enact this activity, knowledge elements required include preparing specific boats, e.g. knowing about the boats weight, capacity, maximum speed and so on are needed. This specific knowledge requires additional local external knowledge resources. For instance, the external knowledge sources that are required for this particular goal can be identified from the 'Annex E: Template evaluation warning, Evacuation order and All clear' of the SES NSW DISPLAN template. In the next version of the framework, such external sources will be incorporated. This will be illustrated in the next chapter. The next chapter will further validate the generalisability of the framework by using a case study from Victoria (rather than NSW). In Victoria, a different template is deployed by SES VIC. This will lead to a different set of customised agent-based modelling templates.

7 The 3rd framework evaluation: *Reduced ABM set and Identifying External Knowledge Sources*

Chapter 6 second evaluation illustrated a more efficient version of the framework. It also illustrated its effectiveness with a post-evaluation engaging a DM expert from the SES NSW. The usefulness of the knowledge output of the framework was confirmed. In other words, the framework is clearly effective and the efficiency issues have been largely addressed with using disaster management templates to drive the analysis process. Nevertheless, the second evaluation still identified further scope to improve the framework. The improvements will be implemented and illustrated in this chapter. As discussed in Chapter 6, they are the following:

1. The ABM set will be reduced to 6 agent modelling templates instead of 7. *The agent model* will be excluded. All elements in that model can flow from the other models as observed in Chapter 6.

2. As highlighted in the post evaluation in Chapter 6, few activities described in some knowledge elements require some additional parameters before they can be enacted e.g. knowing about the evacuation boats weight, capacity, maximum speed and so on are needed. This specific knowledge requires additional local external knowledge resources. Incorporating such external resources will be incorporated in the framework.

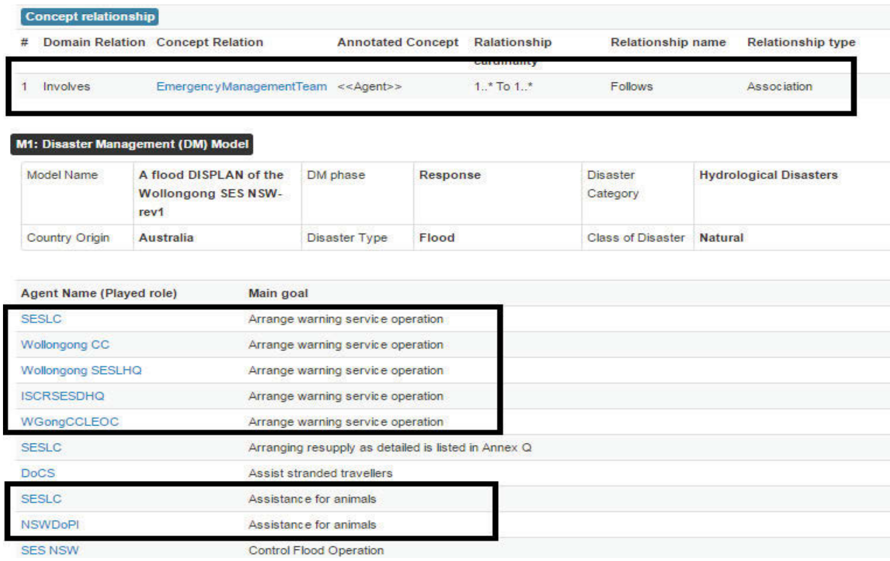
To evaluate these enhancements, a case study of the SES Victoria DISPLAN template is used. In switching the case study to a different context and a different DISPLAN template, this chapter will further confirm the generalisability of the approach. Furthermore, a post-evaluation engaging an expert from Victoria will be undertaken. Thus, the usability and benefit of the knowledge arranged in the repository will be further validated. This chapter is structured as follows: Section 7.1 details the enhancements of the framework and how the framework is evolved. In Section 7.2, the justifications of the employed case study selection are elaborated. Section 7.3 discusses the case study of SES Victoria DISPLAN. Section 7.4 presents the post-evaluation involving a DM expert from Victoria. Section 7.5 concludes this chapter by presenting the final version of the knowledge analysis framework.

7.1 Framework Enhancements

In the context of DM knowledge representation from the DISPLAN, an *agent model* leads to adding a number of concepts in the repository that relate to a particular stakeholder associated with a particular goal. This goal can be relevant along multiple points in the DM timeline (the point in the timeline is identified in a knowledge element *trigger* shown in both models). This is similarly observed for the *scenario model*, but more than one stakeholder is typically involved. In other words, to be able to recognise all agents involving to accomplish an objective, the DM stakeholders need to access and browse all the *agent models* that have the same objective. On the other hand, in the *scenario model*, for the same particular objective as in the *agent model*, all the agents (play roles) are explicitly identified in each of the activities (responsibilities of the agents). In addition, in the *scenario model*, the knowledge elements *pre-, post-condition* and *condition* itself representing before, after and how the activities are undertaken.

The use of the seven ABMs, in Chapter 6, have successfully represented the DISPLAN knowledge and fully transformed into the repository. Thus, ABMs are used descriptively in the context of knowledge representation. However, the *agent model* and *scenario model*, in this context, portray the same representation, i.e. capturing the activities performed by agents in reacting and pro-acting based on perceiving the environment changes. Both models pin down the activities to be performed, resources needed, pre-condition, post-condition prior to performing the activities, the trigger to react and so forth by agent(s). However, while *agent model* only focuses on one particular agent (play a role for performing these activities and using the resources), the *scenario model* integrates all of elements to be more comprehensive. Thus, between both models, employing the one that is more complete is taken. To reduce the cost of modelling activities from modelling, the *agent model* is removed reducing the number of models used to six (instead of seven).

Figure 7.1 highlights the knowledge elements that has been converted into the repository by way of the *goal model*. In the repository, roles of the agents are represented by the concept *EmergencyManagementTeam*. The interface developed for the repository eases the identification process as all the roles are grouped based on the goal that they are involved in. Thus, roles involved in pursuing the goal "*Arranging warning service operation*" can easily be recognised by clicking the link of the goal. In Figure 7.1, for the goal "*Arranging warning service operation*" there are 5 (five) different role involved, namely: Wollongong SESLC, Wollongong City Council, Wollongong SESLHQ, Illawara South Coast Region SESDHQ (ISCRSESDHQ), Wollongong City Council SES Local Emergency Operational Controller (CCLEOC).



Concept relationship

#	Domain Relation	Concept Relation	Annotated Concept	Ralationship cardinality	Relationship name	Relationship type
1	Involves	EmergencyManagementTeam	<<Agent>>	1..* To 1..*	Follows	Association

M1: Disaster Management (DM) Model

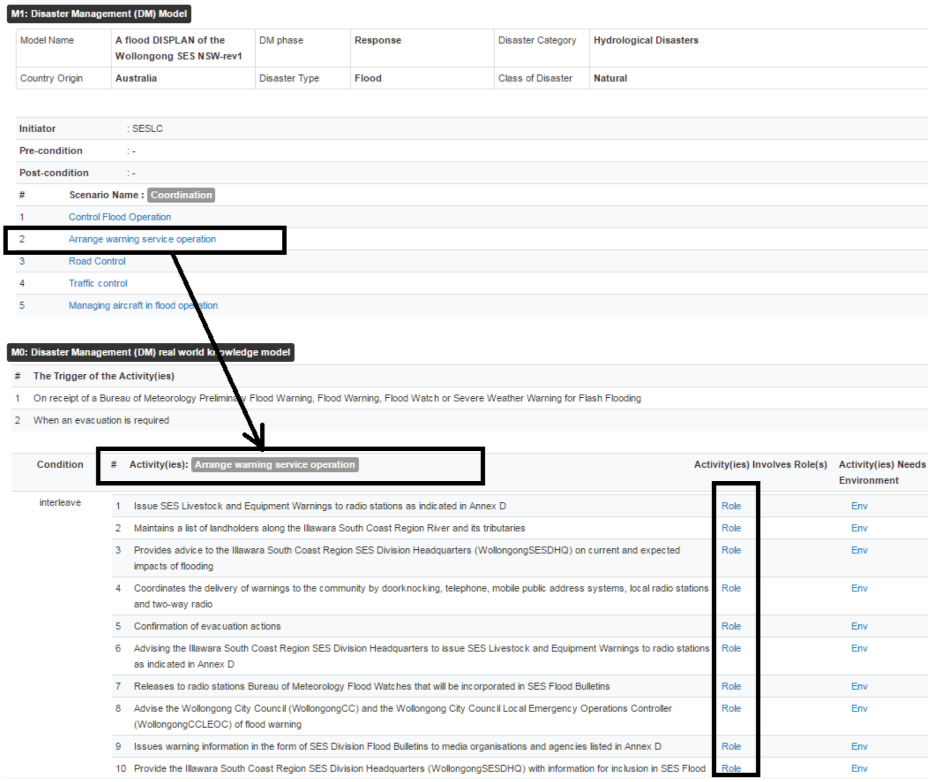
Model Name	**A flood DISPLAN of the Wollongong SES NSW-rev1**	DM phase	**Response**	Disaster Category	**Hydrological Disasters**
Country Origin	**Australia**	Disaster Type	**Flood**	Class of Disaster	**Natural**

Agent Name (Played role)	Main goal
SESLC	Arrange warning service operation
Wollongong CC	Arrange warning service operation
Wollongong SESLHQ	Arrange warning service operation
ISCRSESDHQ	Arrange warning service operation
WGongCCLEOC	Arrange warning service operation
SESLC	Arranging resupply as detailed is listed in Annex Q
DoCS	Assist stranded travellers
SESLC	Assistance for animals
NSWDoPI	Assistance for animals
SES NSW	Control Flood Operation

Figure 7.1 Knowledge of 5 agents pursuing the same goal *ArrangingWarningServiceOperation* in the repository.

Figure 7.2 highlights the knowledge elements that has been converted into the repository by way of the *scenario model*. These elements include *triggers* of the activities. Clicking on these triggers, the interface shows the goal, all activities associated with the goal, and all roles associated with the activities and resources needed. Thus roles to achieve a goal can be easily identified. Roles involved can be easily accessed by "clicking" each of the goals (as shown in Figure 7.2). In other words, all the knowledge elements acquired by way of the scenario models constitute a superset of all those acquired by way of the agent model. Therefore, to improve the efficiency in the customising process of the framework, instead of 7 (seven), 6 (six) ABMs are used in representing the DM characteristic of the DISPLAN: *goal model, role model, organisation model, interaction model, environment model* and *scenario model*. The *agent model* is excluded. This constitutes the first enhancement targeting the efficiency of the framework yet further.

The second enhancement targets at providing more details for the activities involved in DM. Towards this, a pathway for knowledge transfer reflecting the local characteristics is added. The post-evaluation conducted by the DM expert in Chapter 6 showed that some knowledge elements describing the real knowledge activities require additional details to enable their operationalisation. Some details beyond of what is available in the DISPLANs are needed. The given example in post-evaluation in Chapter 6 about of the goal "*flood evacuation warning*" is presented to illustrate this. The Annex E: 'Template evaluation warning, Evacuation order and All clear' of the DISPLAN SES NSW provides the necessary external knowledge elements to detail and complete this goal for the real world responders. Thus, a further analysis to incorporate more detail knowledge elements is by synchronising and substituting them as necessary accordingly into the ABMs of the SES Wollongong flood DISPLAN as these details describing the local characteristics of the Wollongong Municipality. In the framework, this process is part of generating process.



M1: Disaster Management (DM) Model

Model Name	A flood DISPLAN of the Wollongong SES NSW-rev1	DM phase	Response	Disaster Category	Hydrological Disasters
Country Origin	Australia	Disaster Type	Flood	Class of Disaster	Natural

Initiator	: SESLC
Pre-condition	: -
Post-condition	: -

#	Scenario Name : Coordination
1	Control Flood Operation
2	Arrange warning service operation
3	Road Control
4	Traffic control
5	Managing aircraft in flood operation

M0: Disaster Management (DM) real world knowledge model

#	The Trigger of the Activity(ies)
1	On receipt of a Bureau of Meteorology Preliminary Flood Warning, Flood Warning, Flood Watch or Severe Weather Warning for Flash Flooding
2	When an evacuation is required

Condition	#	Activity(ies): Arrange warning service operation	Activity(ies) Involves Role(s)	Activity(ies) Needs Environment
interleave	1	Issue SES Livestock and Equipment Warnings to radio stations as indicated in Annex D	Role	Env
	2	Maintains a list of landholders along the Illawara South Coast Region River and its tributaries	Role	Env
	3	Provides advice to the Illawara South Coast Region SES Division Headquarters (WollongongSESDHQ) on current and expected impacts of flooding	Role	Env
	4	Coordinates the delivery of warnings to the community by doorknocking, telephone, mobile public address systems, local radio stations and two-way radio	Role	Env
	5	Confirmation of evacuation actions	Role	Env
	6	Advising the Illawara South Coast Region SES Division Headquarters to issue SES Livestock and Equipment Warnings to radio stations as indicated in Annex D	Role	Env
	7	Releases to radio stations Bureau of Meteorology Flood Watches that will be incorporated in SES Flood Bulletins	Role	Env
	8	Advise the Wollongong City Council (WollongongCC) and the Wollongong City Council Local Emergency Operations Controller (WollongongCCLEOC) of flood warning	Role	Env
	9	Issues warning information in the form of SES Division Flood Bulletins to media organisations and agencies listed in Annex D	Role	Env
	10	Provide the Illawara South Coast Region SES Division Headquarters (WollongongSESDHQ) with information for inclusion in SES Flood	Role	Env

Figure 7.2 The knowledge activities for pursuing the goal *ArrangingWarningServiceOperation*.

In addition to this, the process can potentially be expedited by engaging a DM expert to pin point the incomplete and less detail of the knowledge elements in the model. Figure 7.3 shows the two enhancements in the framework. Compared to the improved framework from the Chapter 6, the two component enhancements: the number of ABMs is set to reduce to only 6 ABMs (instead of 7 as in the previous evaluation) and examining external resources are added.

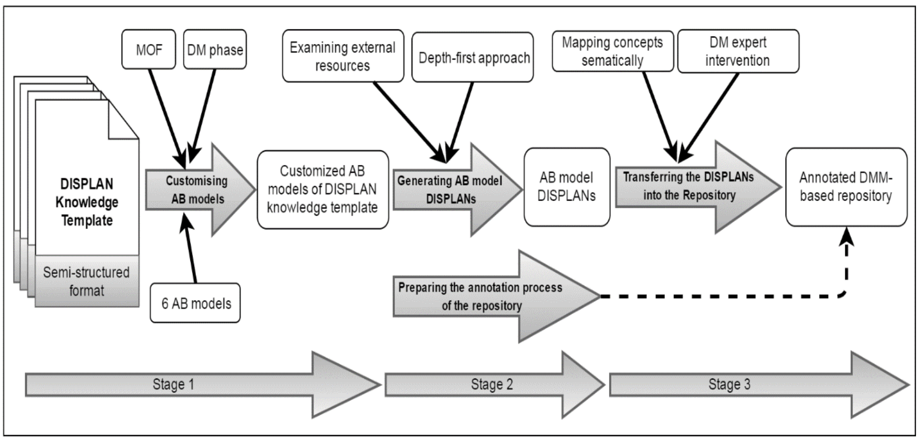


Figure 7.3 The enhanced of knowledge transfer analysis framework to be evaluated.

7.2 Case Study: the SES Victoria Flood DISPLAN knowledge template

A case study from the SES Victoria DISPLAN template of Australia is chosen as the final case study in this thesis. There are two reasons of this: (1) As the overall's framework stages are unchanged except for the enhancements in Stage 1 indicated previously, the use of a case study from the SES State of Victoria (instead of SES NSW) is with the aim to ascertain the generalisability of the framework to be implemented in other areas with the same structure. Similar to the NSW State, the State of Victoria has the same hierarchy administration. In other words, this framework paves the way to be potentially implemented in other countries with the same government structure; (2) The flood disaster, the same type of disaster as previously in both case studies, is taken in this third evaluation due to the fact that it is not only issues in under-developed countries but also the developed ones (Scerri *et al.*, 2012b). In fact, although it is largely a dry continent, Australia now experiences severe flooding across the States (Cavallo, 2014). On top of these reasons, a flood DISPLAN is employed in this evaluation as it maintains the consistency with the same type of disaster in the first and the second evaluations. This allows the framework evaluation to be rigorously concluded at the end.

Similar to the one in the NSW State, the State of Victoria also consists of regions and municipalities. There are 80 Municipalities administered in 17 regions (Regional Development Victoria, 2016). The State of Victoria SES (VICSES) is the DM agency in the State level that is responsible to combat the flood disaster. As in the NSW State, there is also a flood DISPLAN template in the State of Victoria developed to maintain the consistency for the planner to be used to create the one in the Municipality level. This template is used as the input for the enhanced framework to produce the customised ABMs of the flood DISPLAN of the State of SES Victoria. In the evaluation, the ABMs of flood DISPLAN of the Moira Shire Municipality is generated out of the templates and subsequently transferred into the repository. Both template and the original DISPLAN of the municipality can be obtained freely from the SES Victoria website: https://www.ses.vic.gov.au/. It is worth nothing that the knowledge elements that are customised in the ABMs of the SES Victoria might have commonalities with the ones of the SES NSW (in Chapter 6). This due to the fact that they both describe the same DM domain of flood. However, the customising SES Victoria DISPLAN in this chapter is for the State of Victoria.

In this evaluation, the Moira Shire Municipality is chosen to generate its DISPLAN randomly as it is aimed to demonstrate that any city under the same hierarchy level can develop its own DISPLAN based on the template one. Subsequently, that particular Municipality can adapt and synchronise the DISPLAN instantiated with the local wisdom knowledge to adopt all the best lessons learnt from the template. Eventually, the DISPLAN is reserved in the repository to be reused for the basis of decision making mechanism. The detail of the case study being implemented in the framework will be elaborated in the following sections.

7.3 Knowledge Analysis Framework of the third evaluation

As in Chapter 6, in this evaluation, the 3 (three) main stages of the framework remain the same (as shown in Figure 7.3) except for the two efficient improvements that will are applied in the Stage 1: (1) only six ABMs are customized. These six ABM templates will be used to customise the flood DISPLAN template of the SES Victoria as the input to the framework. This results in customised ABMs of flood DISPLAN knowledge of the SES Victoria. Once the customised ones are in place, the generation process of the Moira Shire Municipality DISPLAN takes place; (2) The involvement of the DM expert from the SES Victoria, where the case study is originated, examines all knowledge elements in the models whether they should be more clarified with the corresponding external knowledge resources to be fully comprehended or they have sufficiently represented the real world activities. The stages of the enhanced framework in this evaluation is described as follows:

Stage 1: As the one in the Chapter 6, however, in this evaluation the customising process only applies to six ABMs.

Stage 2: The processes in this stage are similar to the ones in the Chapter 6, however as the DISPLAN template used is from the SES Victoria, the depth-first approach is used to generate a unique plans; in this evaluation is the ABMs of the Moira Shire Municipality DISPLAN. The external knowledge sources are then identified to complete the ABMs of the Moira Shire DISPLAN to be more detail representing the local wisdom of the Municipality. In the process, the DM expert who has agent-based modelling understanding identifies all the elements in each of the ABMs to determine whether or not they have been sufficiently informing the detail of local characteristics of the Moira Shire Municipality.

Stage 3: This is a knowledge transfer stage as the one in Chapter 6. In this stage, the ABMs of the SES Moira Shire Municipality DISPLAN is transferred to the repository.

7.3.1 Stage 1: Customising the Six ABMs of the SES Victoria DISPLAN template

In this stage, the flood DISPLAN SES Victoria is customized. There are only six ABMs (excluded *agent model*) that will be used in this customising activities. A knowledge engineer analyses the flood DISPLAN template of the SES Victoria and models all the knowledge elements into each of the corresponding ABM templates. The result is the six customized ABM DISPLAN templates of the SES Victoria (included in Appendix E in this thesis). Similar to the ones in Chapter 6 in term of producing the customised ABMs, however, in this evaluation these six customised ABMs of the SES Victoria flood DISPLAN will be the foundation to generate local plans for Municipalities within the State of Victoria efficiently (as the use of SES Victoria DISPLAN as the input of the framework), such as Geelong, Monash, Latrobe, Moira Shire effectively as the framework provide a depth-first mechanism to guide the knowledge engineer on how to do it in detail. The details are elaborated as follows:

7.3.1.1 Customising the goal model

Customising the *goal model* is with the aim to produce a customised *goal model* of flood DISPLAN of the SES Victoria as drawn in Figure 7.4. As in Chapter 6, however, the customised *goal model* produced in this evaluation is for the SES Vitoria and therefore it will be the basis to generate a *goal model* for any Municipality DISPLAN under the State of Victoria. A main goal "*evacuation*" is identified as an example for the *goal model* template. Following main goal identification, the <*Municipality*> IC (Incident Controller) as its *initiator* is identified. All the sub-goals and the roles responsible for each of them are the following to be identified. For instance, a sub-goal "*Managing the evaluation process*" and the roles responsible for are VICPOL (Victoria Police) and the <*Municipality*> IC themselves. Once this model is completed, the knowledge engineer designates each of the knowledge elements in this model following the MOF framework as either *M0* or *M1*.

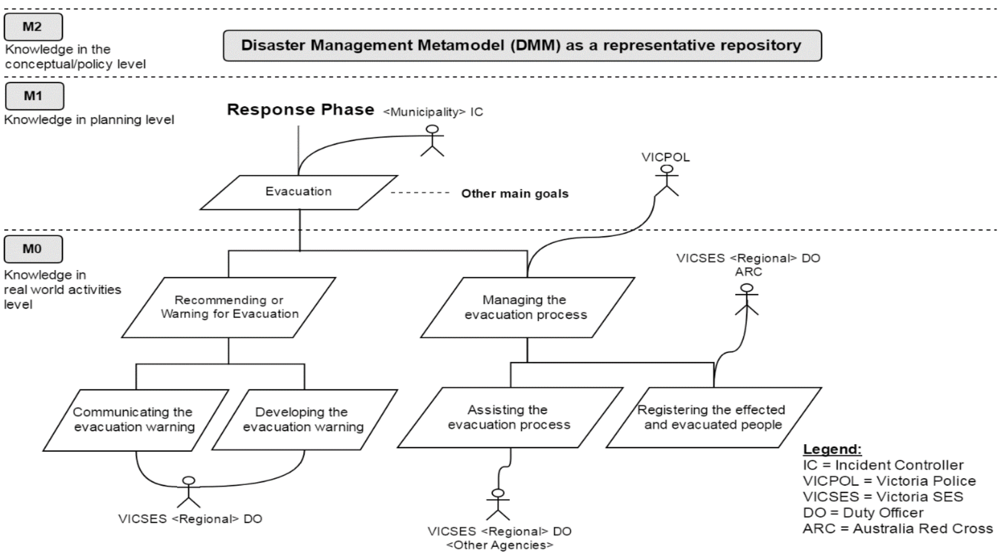


Figure 7.4 A customized *goal model* of the DISPLAN of the SES Victoria for a main goal "*Evacuation*".

7.3.1.2 Customising the role model

The customising the *role model* is based on the customised *goal model*. In this evaluation, the customising *role model* is drawn based on the customised *goal model* in Figure 7.4. The aim is to produce the customised *role model* of the flood DISPLAN of the SES Victoria. Eventually, the knowledge engineer marks the knowledge elements in the *role model* as either *M1* or *M0*. Table 7.1 shows the customised *role model* for only one role *R2*: VICSES <*Regional*> DO.

Table 7.1 Customized *role model* of the flood DISPLAN template of the SES Victoria.

DMM-based repository		*M2*
Role knowledge		**MOF layer**
Role ID	R2	*M1*
Role Name	VICSES <Regional> DO	
Description	If the knowledge analysed and modelled is from North East Region area, then the <Regional > becomes North East Region DO.	
Responsibility	1. Communicating the evacuation warning. 2. Developing the evacuation warning. 3. Assisting the evacuation process. 4. Registering the affected and evacuated people.	*M0*
Constraint	-	

Similar to the customising process in Chapter 6, however as the DISPLAN template is from the State of Victoria, any *role model* for any Municipalities under the State can then be generated efficiently as they can conform to the customised *role model* of the SES Victoria DISPLAN.

7.3.1.3 Customising the organisation model

As in the customising the *role model*, in the *organisation model*, the knowledge engineer refers to the *goal model* to be able to obtain all the roles subsequently laying them down in the customising the *organisation model*. This is illustrated in Figure 7.5.

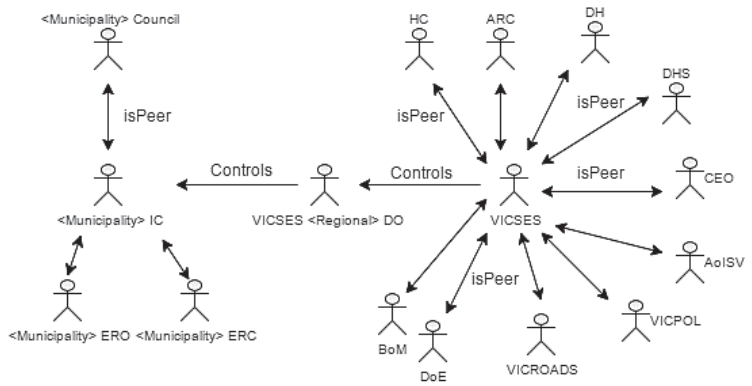


Figure 7.5 Customised *organisation model* of flood DISPLAN of the SES Victoria.

Once the *organisation model* template is in place the knowledge engineer marks each of the elements in the model as either *M1* or *M0*. This is shown in Table 7.2. As in the previous customised ABMs, this customised *organisation model* of Victoria DISPLAN can efficiently generate the ones specified for Municipalities under the State of Victoria efficiently.

Table 7.2 Customised *organisation model* structured in the table based on MOF.

DMM-based repository					*M2*
Organisation knowledge					**MOF layer**
Role A		Organisation knowledge	Role B		*M1*
Role Name	<Municipality> IC	*isControlledBy*	Role Name	VICSES <Regional> DO	
Description	<Municipality> Incident Controller		Description	Victoria <Regional> State Emergency Duty Officer	*M0*
Role Name	<Municipality> Council	*isPeer*	Role Name	<Municipality> IC	*M1*
Description	Playing role as a <Municipality> Council		Description	Playing role as the Association of Independent Schools of Victoria	*M0*
…and so on					

7.3.1.4 Customising the interaction model

As in the previous evaluation, customising the *interaction model* in this evaluation results the customised *interaction model* of flood DISPLAN of the SES Victoria. The knowledge elements in this model are obtained from the customised *goal model*. This is shown in the Figure 7.6. This customised *interaction model* will be the basis to produce the one specified for any particular Municipalities by referring and substituting all the knowledge element classes in this customised one with the local characteristics.

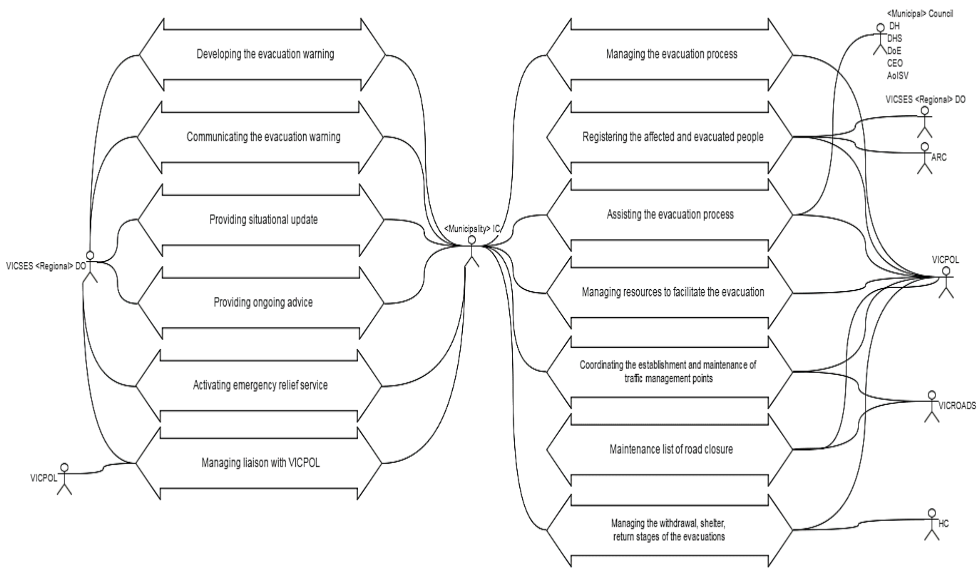


Figure 7.6 Customised *interaction model* of flood DISPLAN of the SES Victoria.

7.3.1.5 Customising the environment model

As in Chapter 6, for customising the *environment model*, a knowledge engineer should revisit the flood DISPLAN template of the SES Victoria to manage it. This produces the customised *environment model* as shown in Table 7.3.

Table 7.3 Customised *environment model* of flood DISPLAN template of the SES Victoria

DMM-based repository			M2
Environment knowledge			**MOF layer**
Environment Entity ID	E14		M1
Environment Name	List of channels for communicating the evacuation warning		
Description	List of the tools to be used by authority to deliver the evacuation warning to the likely impacted community area.		
Attributes	#	Unique number distinguishing inputted data	M0
	Channel type	TV/ Radio/ Text message	
	Warning type	The content of the warning	
Roles Involved	VICSES <Regional> DO		
	<Municipality> IC		

For instance, from the SES Victoria DISPLAN template an environment knowledge element "*List of channels for communicating the evacuating warning*" is identified. Thus, for the element attributes of the model, the elements *channel* and *warning types* are laid down to make detail of the environment element. The element *roles involved* inform that the roles: VICSES <*Regional*> DO and <*Municipality*> IC use this environment knowledge to accomplish their tasks. Once the knowledge elements of the environment are orchestrated into this model, the engineer then designates each of the elements as either *M0* or *M1*. As in previous customised ABMs, this customised *environment model* will also be the basis to generate the one specified for any Municipalities under the State of Victoria.

7.3.1.6 Customising the scenario model

As in Chapter 6, the knowledge elements in the customised *scenario model* are based on other customised models except for the elements *trigger*, *pre-, post-condition* and *condition* itself. It is shown in Table 7.4.

For these elements, the knowledge engineer has to revisit the original DISPLAN to structure them. Once the model is completed and subsequently all the elements in this model are marked as either *M1* or *M0* representing the knowledge in the policy/planning level or real world activities, respectively. As the one in Chapter 6, however, the customised *scenario model* in this evaluation is specified for the basis to generate any Municipalities DISPLAN under the State of Victoria.

Table 7.4 Customised *scenario model* of flood DISPLAN template of the SES Victoria.

<table>
<tr><th colspan="5">DMM-based repository</th><th>M2</th></tr>
<tr><th colspan="5">Scenario knowledge</th><th>MOF layer</th></tr>
<tr><td colspan="2">Scenario</td><td colspan="3">S9</td><td rowspan="4">M1</td></tr>
<tr><td colspan="2">Name</td><td colspan="3">Evacuation scenario</td></tr>
<tr><td colspan="2">Goal</td><td colspan="3">Evacuation</td></tr>
<tr><td colspan="2">Initiator</td><td colspan="3"><Municipality> IC</td></tr>
<tr><td colspan="2">Trigger</td><td colspan="3">▪ Properties are likely to become inundated;
▪ Properties are likely to become isolated and occupants are not suitable for isolated conditions;
▪ Public health is at threat as a consequence of flooding;
▪ Essential services have been damaged and are not available to a community and evacuation is considered the most effective risk treatment.</td><td rowspan="12">M0</td></tr>
<tr><td colspan="2">Pre-condition</td><td colspan="3"><Municipality> IC in consultation with <Municipality> ERC, <Municipality> ERO, DHS, DH, BoM, CMA, HC and VICPOL for the evacuation based on the triggers.</td></tr>
<tr><td colspan="2">Post-condition</td><td colspan="3">The evacuation decision is released by <Municipality> IC</td></tr>
<tr><td colspan="2">Description</td><td colspan="3">The evacuation is aimed to protect people from the risks of an emergency. This is conducted by evacuating people from a specific locality such as an institution (educational or hospital), a town or an area of the state.</td></tr>
<tr><td>Condition</td><td>Step</td><td>Activity</td><td>Role</td><td>Environment Entity</td></tr>
<tr><td rowspan="6">-</td><td>1</td><td>Recommending or warning for evacuation</td><td>R1</td><td></td></tr>
<tr><td>2</td><td>Communicating the evacuation warning</td><td>R1, R2, R3, R4</td><td>E14</td></tr>
<tr><td>3</td><td>Developing the evacuation warning</td><td>R1, R2, R3</td><td>E1</td></tr>
<tr><td>4</td><td>Managing evacuation process</td><td>R1, R7</td><td></td></tr>
<tr><td>5</td><td>Assisting evacuation process</td><td>R1- R11</td><td></td></tr>
<tr><td>6</td><td>Registering the affected and evacuated people</td><td>R1, R2</td><td>E19</td></tr>
</table>

7.3.2 *Stage 2: Generating six ABMs of the Moira Shire Municipality DISPLAN*

All the generating process in this stage are based on the customised ABMs of flood DISPLAN of the SES Moira Shire Municipality of the previous stage. The process itself is similar to the one described in the Chapter 6. Each of the ABMs from the customised stage produces the unique ones for the Moira Shire DISPLAN. However, as earlier discussed in Section 7.1 the second enhancement in this evaluation is at targeting more detail describing the specific characteristics representing the Moira Shore Municipality takes place in this stage. The specific knowledge elements for specifying the detail are acquired from the external sources that initially are not part of the elements in the main body of the DISPLAN such as Appendices A-F (SES Victoria Australia, 2011). The details of the generating processes are elaborated as follows:

7.3.2.1 Generating the goal model

As in the Chapter 6, in this evaluation, all the knowledge element classes are substituted to the ones representing the Moira Shire Municipality. The process then results the *goal model* of flood DISPLAN of the Moira Shire Municipality, as seen from Figure 7.6. The basis to generate the *goal model* of flood DISPLAN of the SES Moira Shire is based on the customised the goal model of the SES Victoria as shown in Figure 7.4. All the knowledge elements in the customised *goal model* that need further scrutinise are identified by the knowledge engineers (DM expert who has ABMs understanding or an engineer who has DM expertise background). Based on this is evaluation, some element goals in the model are required to be more drilled down to be more comprehensively understood. The knowledge engineer then goes to identify the external resources that are useful to complement the existing goals in the model.

For instance, for the goal "*recommending or warning for evacuation*", there should be sufficient information required by the Moira Shire IC to make the decision. This will be based on the predicted gauge heights or likely occur of the flood and the times to evacuate. In addition, once the evaluation warning is issued, there should be a detail arrangement for the evacuation based on the characteristics of the Moira Shore Municipality, such as routes to be taken, the locations of the shelter for human and animals, the evacuation location for the caravans. All these particular knowledge elements are identified from the in an Appendix C "Flood Emergency Plan" for the list for the river gauge locations in the Moira Shire Municipality to make the evacuation decision and in Appendix D: "Flood Evacuation Arrangement" for arranging the evacuation of the SES DISPLAN template.

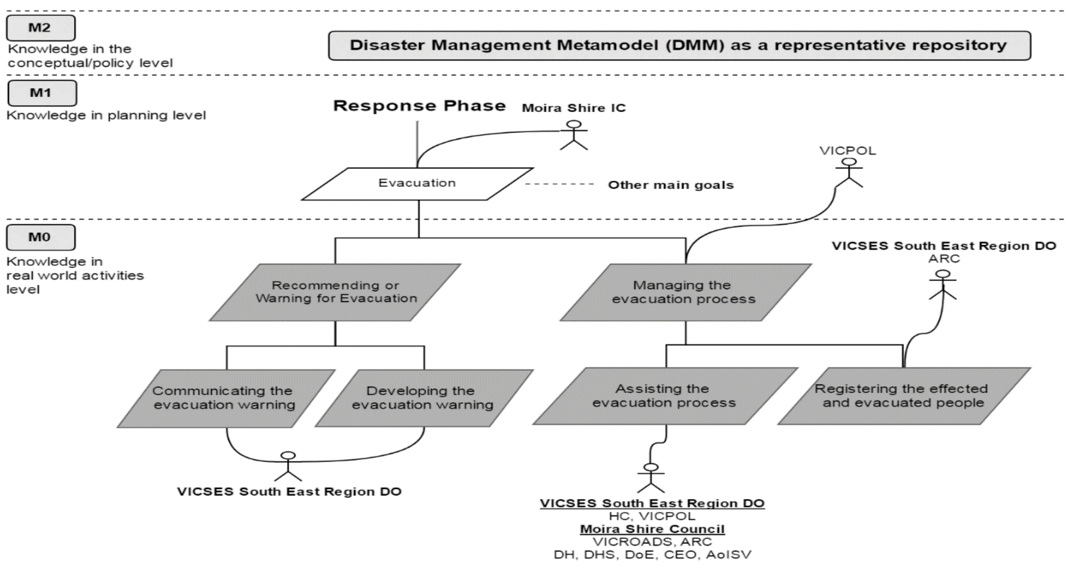


Figure 7.6 The *goal model* of the flood DISPLAN of the Moira Shire Municipality.

7.3.2.2 Generating the role model

As in the *goal model*, generating process of the *role model* means that all the substitutable knowledge elements in the *role model* template will be replaced with ones representing the local wisdom of the Moira Shire Municipality. In Table 7.5, the *role model* of flood DISPLAN knowledge of the SES Moira Shire Municipality is shown. It describes all responsibilities of the role *R2*, VICSES South East Region DO, being involved in pursuing the objective.

Table 7.5 The *role model* of the flood DISPLAN of the Moira Shire Municipality.

DMM-based repository		*M2*
Role knowledge		**MOF layer**
Role ID	R2	*M1*
Role Name	VICSES **<~~Regional~~> South East Region** DO	
Description	If the knowledge analysed and modelled is from North East Region area, then the <*Regional*> becomes North East Region DO.	
Responsibility	1. Communicating the evacuation warning. 2. Developing the evacuation warning. 3. Assisting the evacuation process. 4. Registering the affected and evacuated people.	*M0*
Constraint	-	

7.3.2.3 Generating the organisation model

Generating the *organisation model* instantiates the *organisation model* of flood DISPLAN of the SES Victoria from the customised one. This is conducted by substituting all the knowledge element classes in the customised organisation model with ones representing the Moira Shore Municipality. In Figure 7.7., the generating process of this model is drawn. As can be seen the element classes <*Municipality*> and <*Regional*> are substituted with the ones representing Moira Shire Municipality and South-East Region respectively.

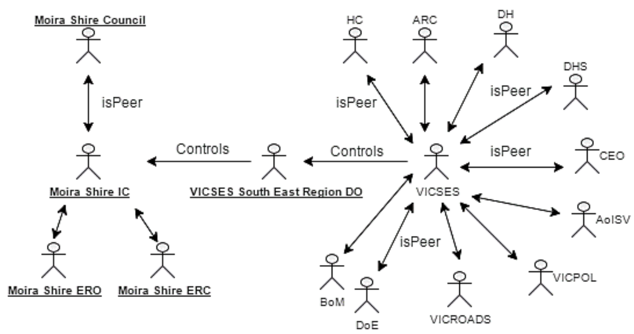


Figure 7.7 The *organisation model* of the flood DISPLAN of the Moira Shire Municipality.

7.3.2.4 Generating the interaction model

Similar to the generating process of the *interaction model* in Chapter 6, this results in the *interaction model* of flood DISPLAN of the Moira Shire Municipality as shown in Figure 7.8.

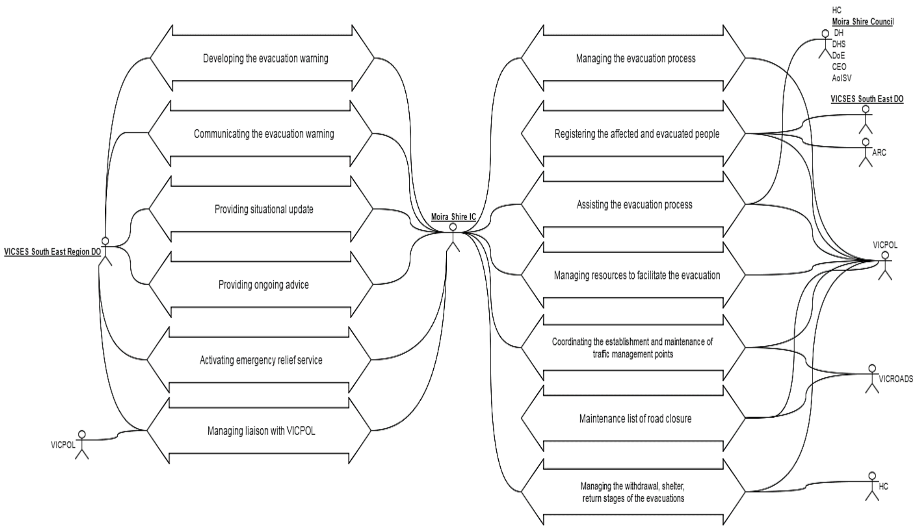


Figure 7.8 The *interaction model* of the flood DISPLAN of the Moira Shire Municipality.

7.3.2.5 Generating the environment model

This step produces the *environment model* of flood DISPLAN of the Moira Shire Municipality. Table 7.6 shows the result of this process. In the table, the environment knowledge "*List of channels for communicating the evacuation warning*" is shown. It is denoted in the *environment model* as *E14-th* of the environment knowledge identified from the elements within the main goal "*evacuation*" (see the *goal model*). From the table, the role classes in the element *roles involved* are substituted to refer to the South East Region and Moira Shire Municipality respectively.

Table 7.6 The *environment model* of the flood DISPLAN of the Moira Shire Municipality.

DMM-based repository			M2
Environment knowledge			**MOF layer**
Environment Entity ID	E14		M1
Environment Name	List of channels for communicating the evacuation warning		
Description	List of the tools to be used by authority to deliver the evacuation warning to the likely impacted community area.		
Attributes	#	Unique number distinguishing data	M0
	Type	TV/ Radio/ Text message	
	Warning type	The content of the warning	
Roles Involved	**VICSES <~~Regional~~> South East Region DO**		
	<~~Municipality~~> Moira Shire IC		

7.3.2.6 Generating the scenario model

The last ABM that undergoes the generating process is the *scenario model* template. In this third evaluation, it is the Moira Shire Municipality. Table 7.7 shows the generating process to produce the *scenario model* of the flood DISPLAN of the SES Moira Shire Municipality. As in Chapter 6, a knowledge engineer examines all the elements in the model template to substitute with the ones representing a particular municipality.

Table 7.7 The *scenario model* of the flood DISPLAN of the Moira Shire Municipality.

DMM-based repository					M2
Scenario knowledge					**MOF layer**
Scenario		S9			M1
Name		Evacuation scenario			
Goal		Evacuation			
Initiator		**<~~Municipality~~> Moira Shire IC**			
Trigger		▪ Properties are likely to become inundated; ▪ Properties are likely to become isolated and occupants are not suitable for isolated conditions; ▪ Public health is at threat as a consequence of flooding; ▪ Essential services have been damaged and are not available to a community and evacuation is considered the most effective risk treatment.			M0
Pre-condition		**<~~Municipality~~> Moira Shire IC** in consultation with **<~~Municipality~~> Moira Shire ERC**, **<~~Municipality~~> Moira Shire ERO**, DHS, DH, BoM, CMA, HC and VICPOL for the evacuation based on the triggers.			
Post-condition		The evacuation decision is released by **<~~Municipality~~> Moira Shire** IC			
Description		The evacuation is aimed to protect people from the risks of an emergency. This is conducted by evacuating people from a specific locality such as an institution (educational or hospital), a town or an area of the state.			
Condition	Step	Activity	Role	Environment Entity	
--	1	Recommending or warning for evacuation	R1	E14	
	2	Communicating the evacuation warning	R1, R2, R3, R4	E14	
	3	Developing the evacuation warning	R1, R2, R3	E1	
	4	Managing evacuation process	R1, R7		
	5	Assisting evacuation process	R1- R11		
	6	Registering the affected and evacuated people	R1, R2	E19	

7.3.3 Stage 3: Knowledge transfer

As in Chapter 6, there are 2 (two) activities in this stage: 1) Preparing the repository. The repository remains similar as the one from the previous evaluation as there is nothing to be changed; and; 2) Transferring the ABMs of the Moira Shire flood DISPLAN to the repository. Figure 7.8 show the Moira Shire flood DISPLAN that is transferred to the repository. Figure 7.9 shows how the Moira Shire flood DISPLAN knowledge structured in the repository. As in Chapter 6, a post-evaluation is also conducted in this evaluation as the enhancements of the framework. This post-evaluation is performed by a DM expert from the SES Victoria where the case study come from. This is discussed in the following section.

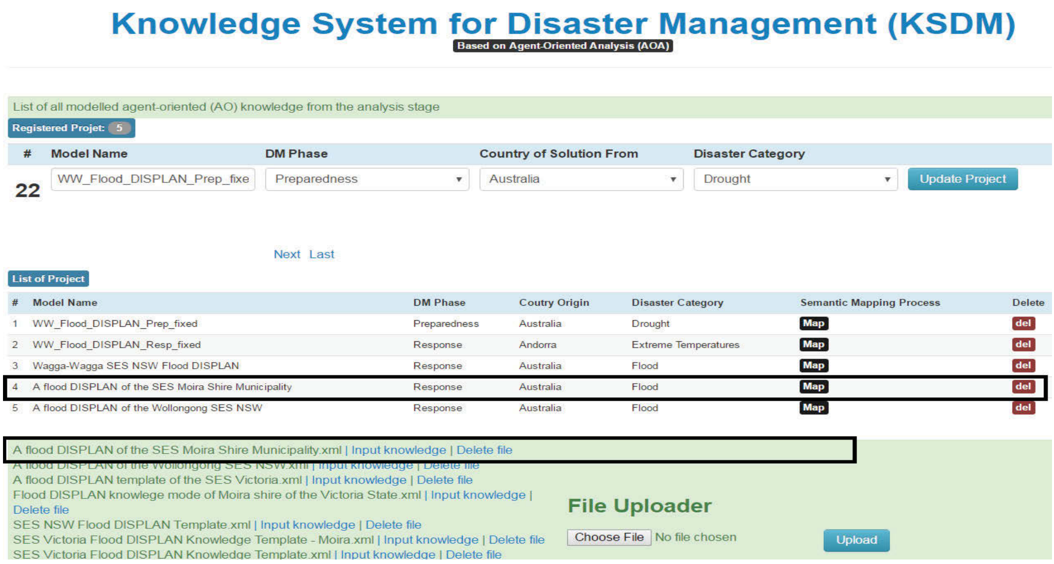


Figure 7.8 The ABMs of the flood DISPLAN of the Moira Shire transferred into the repository.

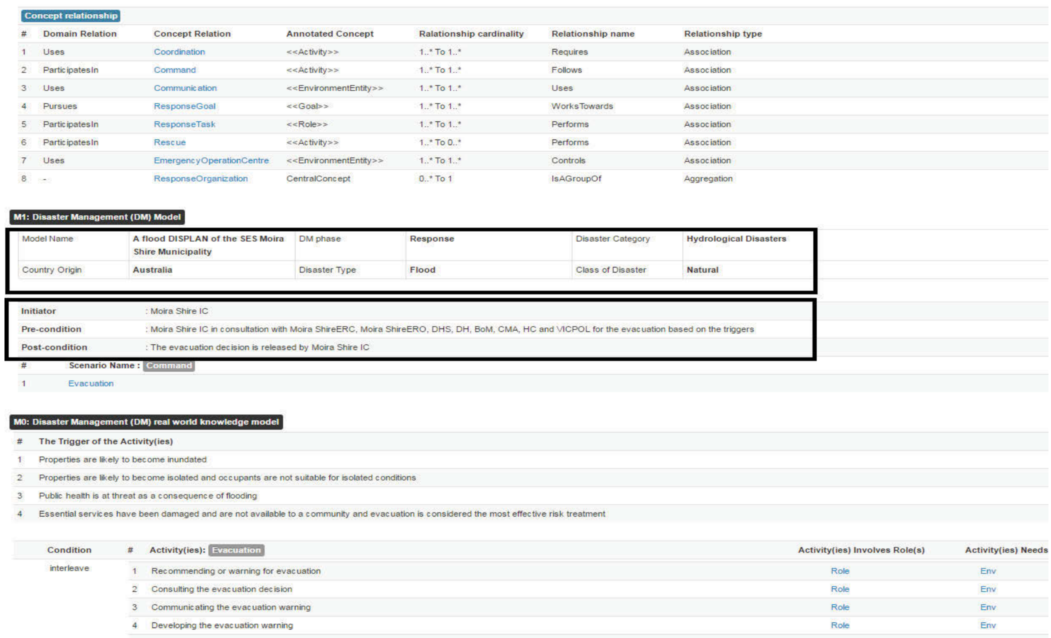


Figure 7.9 The structure of Moira Shire flood DISPLAN knowledge in the repository.

7.4 Post-evaluation of the SES Victoria case study

Similar with the one in Chapter 6, a post-evaluation is also undertaken in this chapter due to further enhancements that are applied to the framework: 1) Only 6 (six) instead of 7 (seven) ABMs in the customising processes and 2) utilising the external knowledge sources to provide a more complete and detail knowledge element in the ABMs. The detail evaluation by the DM expert is shown in Table 7.8. These enhancements are validated using the real case study from the SES State of Victoria DISPLAN template. The template is the foundation to generate the Moira Shire Municipality SES DISPLAN.

Table 7.8. Evaluation outcome of benefits and usability of the deposited knowledge from the DM expert of the SES State of Victoria.

Addressing criteria	Outcome	DM Expert's comment
Knowledge in the repository is unchanged from its original	Y	"The knowledge meaning in the DISPLAN and in the AB models is still the same. It gets reworded in some part just to emphasize the meaning".
The use of DISPLAN knowledge template instead of a unique plan increases the efficiency in and developing other plans.	Y	"Moving to an approach such as is proposed here would enable the complexities of emergency planning for floods to better planned for. It would also support a model that provides flexibility to be adapted to different risk profiles across municipalities. A pilot approach would be a suitable approach to test and validate such a new process."
New knowledge representation in the repository is comprehended more effective and efficient.	Y	"More than this however is that the interleaving and sequential nature of the elements of the models that enable the full picture to be built within the plan to enable DISPLANS to more effectively plan for the complexities of disasters and assign resources to respond to disasters. This includes contributing to role clarity of stakeholders".
Incomplete knowledge can be identified systematically	Y	"This might also provide a good lead in to provide material for exercises to be undertaken to test the DISPLAN".
The new knowledge representation can help DM stakeholders in a better decision-support system mechanism.	Y	"It is also important to understand timing for the onset of consequences, duration of inundation and the time for floodwaters to recede".
New knowledge structure in the repository helps DM stakeholder in identifying appropriate response at any point of the disaster timeline.	Y	"There is also an significant hurdle of implementing an effective change management process to ensure that more than just having a good comprehension of English, practitioners would also be expected to adopt a new way of developing DISPLANS".
Overall, the framework contributes in DM resilience agenda	Y	"The framework could also provide a mechanism or some tools to help DM experts to communicate with communities about their risks and understand levels of resilience in communities".

As in Chapter 6, this post-evaluation is conducted with the aim to ascertain that the knowledge structure and meaning in the repository is unchanged after all the framework improvements. In particular, the usability and benefits of the knowledge to the target user groups, the DM stakeholders. Therefore, the criteria of this post-evaluation are similar to the ones in the Chapter 6. A DM expert from the SES State of Victoria where the case study is from performs this post-evaluation. All the responses from the expert of this post-evaluation are all positives. This illustrated that using only six ABMs instead of seven is sufficient in the analysis and modelling and had little effect to capturing the complex knowledge out of DM domain. In addition, these evaluations not only asserted the sufficiency of the number of models being used but also demonstrated the improved efficiency in the knowledge analysis and modelling processes compared to the earlier version of the framework.

7.5 Final version of the Knowledge Analysis Framework

In this research, the initial version of the knowledge analysis framework was developed in Chapter 4. This framework then underwent three evaluations with cases studies from SES Wagga-Wagga, SES NSW and SES State of Victoria in Chapter 5, 6 and this chapter respectively. The aim of these evaluations was to produce a more efficient and effective framework for the knowledge transfer analysis. These evaluations were framed based on the DSR methodology in IS. This section presents the final version of the developed framework. It summarises all the enhancements of the framework. This is drawn in Figure 7.10.

The final version of the framework comprises 3 (three) main stages. Each of them undergoes a set of activities. The initial input is the DISPLAN knowledge template of four DM phases (PPRR) maintained in a semi-structured format. In stage 1, the input of the semi-structured DISPLAN knowledge template is customized with the 6 (six) ABMs: *goal model, role model, organisation model, interaction model*, *environment model* and *agent model*. The customisation process in this stage is analysis and modelling activities. The knowledge elements in the models are designated based on the MOF framework to represent either *M1* or *M0*. The *M2* layer will be left to be reserved for the DMM-based repository concepts. The output of this stage is the customized ABMs of the DISPLAN knowledge which will be the input for the next stage.

In Stage 2, there are 3 (three) activities to be accomplished, namely: 1) generating the ABMs of unique DISPLAN out of the customised ones; 2) reviewing external knowledge resources for more complete local characteristic representation, and; 3) preparing the repository to allow the transfer process. In the first activity (generating ABMs), the customised ABMs serve as the knowledge element classes identified from the DISPLAN template. In the generating activities, a depth-first approach is used. This approach aims to improve the efficiency of the knowledge conversion process as it allows the generating process to be undertaken simultaneously by a number of knowledge engineers.

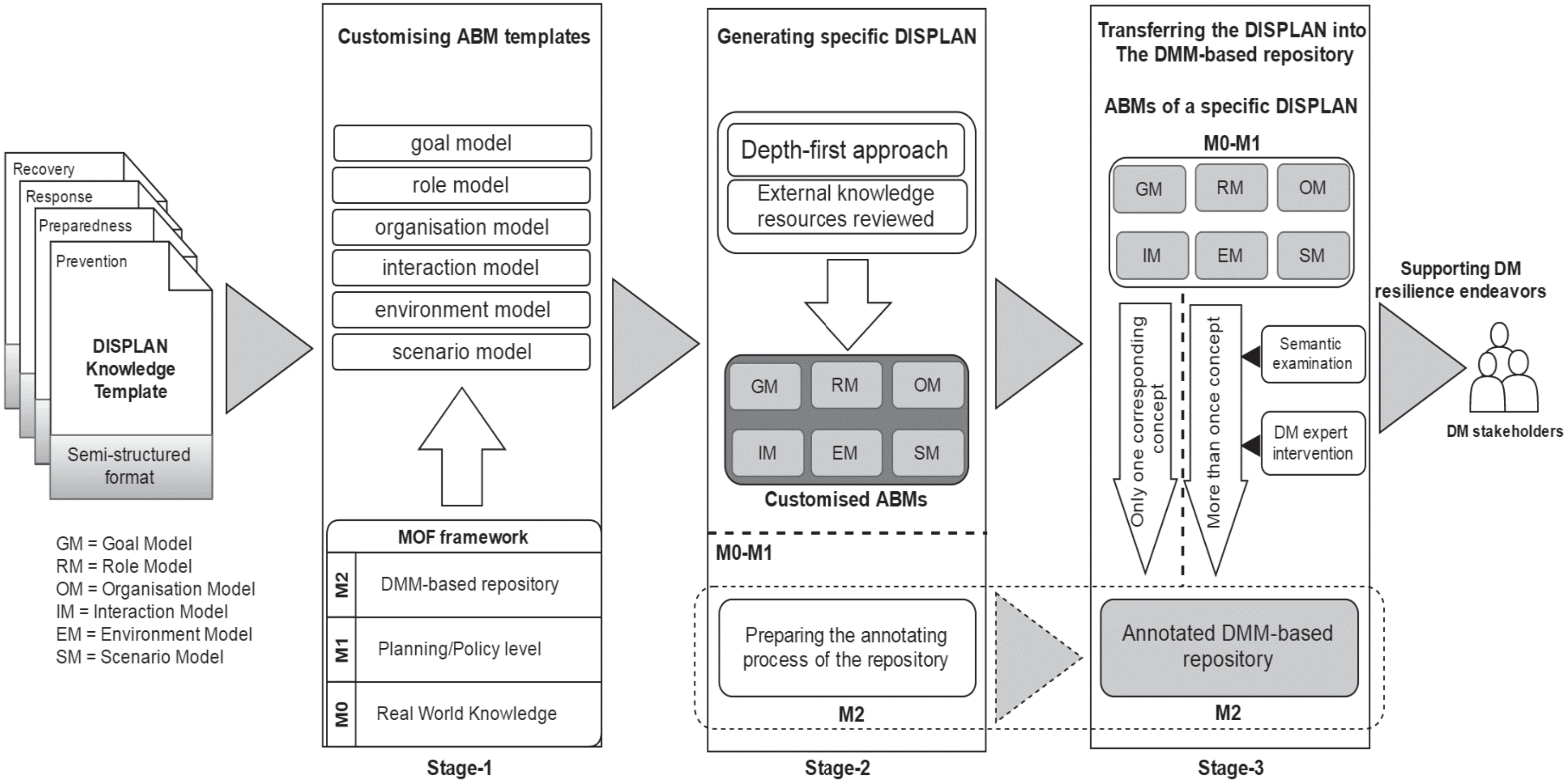


Figure 7.10 The final version of the developed and evaluated of the DM Knowledge Analysis Framework.

The result of the first activity in Stage 2 is the unique DISPLAN in ABMs for particular areas. In the second activity, all the external knowledge resources referring to any element in all the unique ABMs produced from the first activity is reviewed and arranged in the corresponding models to obtain more comprehensive knowledge structures. This will be the input for Stage 3. The third activity is preparing the repository. This is arranged by annotating all the concepts in the DMM with the representative ones of the FAML metamodel concept. The aims is to produce an AB DMM-based repository that allows ABMs to be transferred to it. The annotating process is conducted by augmenting each of the DMM concepts with the corresponding one of the FAML. To guide the augmenting process, a DM expert is involved. The involvement of the DM expert in this process is to ensure that process is conducted correctly. This process results the annotated DMM-based repository.

In Stage 3, the transferring process is arranged. In this stage, the unique DISPLAN being resulted in Stage 2 is transferred to the repository. This process itself is arranged in 2 (two) scenarios: 1) If there is only one representative concept in the DMM repository where the knowledge in the ABMs is to be referred to, the knowledge transfer can be performed directly and automatically; 2) If there will be however more than one appropriate concept in the annotated repository representing the knowledge elements of the ABMs. In this scenario, there is a need of a DM expert engagement in this case to examine the semantic meaning of those differences. Eventually, the expert judges the most appropriate concept that is suitable to be mapped with the knowledge in the ABMs.

It is worth noting that all the activities in these three main stages are explored iteratively. In this sense, a knowledge engineer can always take one step backward at any point to refine the latter process to improve the current one whenever necessary prior to tackling the next one. Revising the process based on the feedbacks in the early stage of the development stage prevents the errors which can propagate to the later phase. Eventually, once the knowledge elements are fully transferred into the repository, they configure a 3D format representing the MOF framework, the concepts of the FAML metamodel and the DM phases themselves. The stakeholders subsequently can formulate the decision-making mechanism based on those three dimensions. In particular, the decisions that can be drawn up from the repository do not only fit in the decision-making layer but more importantly they can be holistically drilled down vertically to the policy/planning layer and into the people on the ground. This is not to mention that the knowledge elements structured in the repository also stretch horizontally to unveil the elements in each layer that are the determinant factors for the DM activities successfulness.

7.6 Construction decision making mechanism based on the framework

Pursuing a better decision making mechanism essentially is the common objective inherently in the KE research streams. KE, according to Studer *et al* (1998), is essentially characterised by these three notions, that it is : (1) modelling activities; (2) a knowledge transfer; and (3) a problem-solving. The first two notions substantially are also key objectives in this thesis with different methods from the existing ones as the contribution. The notion of problem-solving remains at the heart of the decision making process per se. Thus, while the first two notions have been systematically presented their development and validations in this thesis, the third notion fundamentally is inseparable and tightly coupled with the first two. The construction of the first two leads to the third one. Therefore, although the main contribution of this thesis is to develop a DM knowledge analysis framework, it also substantially paves the way to be used to enhance the decision making mechanism in DM. A few illustrations essentially have been presented in this thesis as to how the decision making processes could be performed for the given situations based on the developed framework and tools, specifically in all evaluation chapters (Chapter 5-7).

The decision support mechanism can be executed either bottom up or top down. This is illustrated in Figure 7.11. While the bottom up means that the decision can be formulated based on particular activities rolled up conforming their constructs in the repository, the top down means some concepts in the repository are identified instantiating the real DM activities. Based on MOF, these typical relations are conformance and instantiation respectively. The relations between the knowledge modelled in ABMs units and the DMM-based concepts in the repository also follows these two relation types. In the conformance, once an activity is performed to response to a particular situation, this particular activity needs to point out its more complete knowledge elements in the ABMs, i.e. identifying the roles involved, resources needed, pre- and post-condition of the activity, before abstracting its concept representing the activity in the repository. This enhances decision making process as they allow a more complete knowledge structure to be identified, not only the essential and necessary knowledge elements highlighted but also their corresponding activities. Identifying a concept in the repository representing a particular activity from the real world layer, leads to recognising other related concepts (for the justification as such, please see Section 2.4 of this thesis).

In a particular disaster event, this assists authorities to establish a more complete decision making process. The more complete the recognised knowledge elements is, the better the decision making process can be organised. Following instantiation relations, the way the decision is identified is similar as in the conformance. However, the process is drilled down from the recognising the abstract concepts in the repository through to the activities in the real world layer.

These typical knowledge constructions directly contribute to enhance the strictly delineated PPRR phases as noticed for instance in here (Briceño, 2015a; Cavallo, 2014; Weichselgartner & Pigeon, 2015). Thus, although the knowledge is classified based on the PPRR phases however it is classified based on the urgency in the DM timeline. In other words, the knowledge is structured by distinguishing it in its abstract, planning and performing level. The knowledge in abstract layer is related for decision making. Decision makers are not dealing with the technical level detail of knowledge elements however their decisions need to be interpreted in a way that it can be understood by those who are on the ground. This is the aim the planning layer where the justifications of the decisions are translated in understandable formats. All these decision making processes are targeted at and supported by the developed framework materialised as the prototype for this research.

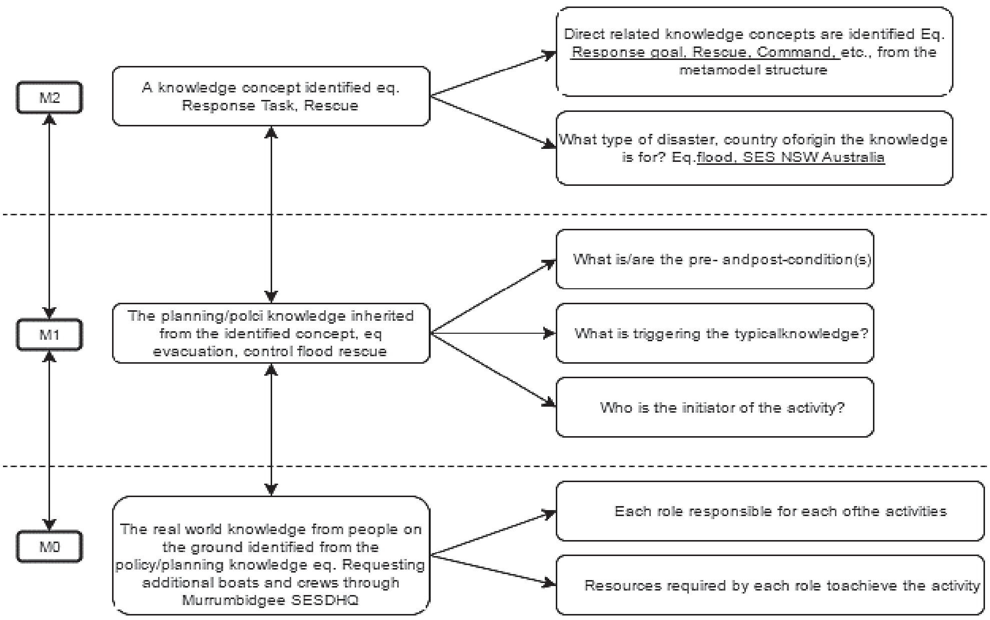


Figure 7.11. Conceptual construction of decision making mechanism based on the framework.

For instance, as the situation in a particular flood event in the Moira Shire Municipality, there is an urgency for "*directing, ordering, or controlling by virtue of explicit statutory, regulatory, or delegated authority*". It is the typical knowledge in the abstraction level which in the DMM, it is represented by the construct "*command*". This urgent activity can also be activated due to triggers from the environment. The adopted ABM paradigm allows representing the activities taken based on the reaction(s) as agent(s) perceiving environment changes. For instance, these triggers (from Figure 7.9): "*Properties are likely to become inundated*", "*Properties are likely to become isolated and occupants are not suitable for isolated conditions*", "*Public health is at threat as a consequence of flooding*", "*Essential services have been damaged and are not available to a community and evacuation is considered the most effective risk treatment*" can also be the factors to activate evacuation-related activities.

Based on the developed tools (for instance as shown in Figure 7.9), the concept "*command*" is then clicked to identify all the knowledge elements of the necessity activities to be performed to response the situation. These activities are, for instance "*evacuation*", "*aircraft management*", "*preliminary deployments*", "*resupply*", etc. and the initiators for each of these activities are recognised, for instance, the initiator of the evacuation is Moira Shire Incident Controller (IC), and so forth. These activities are sourced from the original DISPLANs analysed. For those who are in the planning level, these activities and the initiator might be sufficient to be the guidance for other identifications, nevertheless for those who are in the real world, the activities need to be completed and detailed in the executable formats and at the same time representing the local wisdom. In the developed tools, to obtain these typical knowledge elements required, further clicking for each of the elements will disclose them. For instance, to pursue the "*evacuation*", these activities are set out: "*Recommending or warning for evacuation*", *"Communicating the evacuation warning"*, *"Developing the evacuation warning"*, *"Managing evacuation process"*, *"Assisting evacuation process"* and *"Registering the affected and evacuated people"*.

Further clicking on the "roles" of each of these activities identifies other roles involved. Their interactions and communications to pursue this particular activity can be identified by clicking "environment entity" (resources required by these roles). For instance, while for this activity "*Communicating the evacuation warning*", the roles responsible for it are Moira Shire IC and VICSES South East region DO, the resources needed in this activity are assigned local TVs and radios and mobile text message channel. In the decision making context, these elements roles and environment entity inform that local wisdom of Moira Shore Municipality these knowledge elements represent. Therefore, those who are on the ground can directly execute these typical knowledge elements. This construction of decision making mechanism can also be observed in the other case study evaluation, for instance as described in Chapter 5 and 6. As commonly believed that the more complete the knowledge, the better decision can be made. This is also applied in this context, that is the more complete the knowledge structured in the DISPLAN, the more DM resilience can be pursued. In other words, in this context the knowledge elements in the original DISPLAN is assumed to have been completely recognised to develop a better DM decision support system.

The ultimate evaluation of the framework would need to be measured and evaluated in real world scenarios. This will enable evaluation of the decision making processes based on the developed framework to support the DM resilience endeavours. The evaluation itself in this context is aimed at the analysis framework enabling the decision processes described.

8 Conclusion

This chapter summarises the thesis and reflects on its main results and limitations. The structure of this chapter is as follows: Section 8.1 summarises the conducted research; Section 8.2 lays down the contributions this thesis; Section 8.3 describes the limitation and future research directions; Section 8.4 concludes the chapter and the thesis with final remarks.

8.1 Research Summary

This thesis presented a DM knowledge analysis framework to facilitate the conversion of disaster management plans into a unifying repository. This repository will facilitate sharing and reusing of knowledge in DM domain. The framework utilises agent based modelling as bridge between the DM document sources and a metamodel-based repository. The conversion between the agent-based models and the repository structure is facilitated by the MOF framework and another mapping between the repository metamodel and the metamodel describing the agent based models. The framework as a whole built and evaluated using the Design Science Research (DSR) paradigm. During its development, the framework underwent a series of validations iteratively through some real case studies of flood DISPLAN from the SES agencies in Australia (NSW and Victoria States). The resultant framework was able in facilitating the knowledge transfer analysis for the DM domain. The framework was refined through these evaluations. It was made to become more efficient following the first two case studies. Following these enhancements, post-evaluations were also performed to ascertain the usability and usefulness of the knowledge structure in the repository to the DM stakeholders as the target user group. The DM experts from both the SES agencies (NSW and Victoria) were engaged for the purpose of the post evaluations. They were also engaged to mediate the knowledge transfer into the repository. In particular, they were engaged in resolving instances when there was a one-to-many relationship between the ABMs and the possible appropriate concepts in the repository.

The framework as a product from DSR research activities achieved all the objectives of the thesis as specified in Chapter 1. The summaries of these research activities are outlined as follows:

Phase 1, problem identification. Reuse of DM knowledge is critical. DM knowledge should be managed in a way to allow it to be shared and reused. But the nature of DM knowledge is complex and this shapes the investigation in this thesis. The complex nature of DM knowledge warrants a tailored and a systematic knowledge analysis methodology to codify the DM knowledge for reuse. To facilitate reuse, the outcome of the DM knowledge analysis needs to be deposited in a shared and a suitable repository. The AOA approach utilizing the ABMs from the AOSE paradigm is acknowledged to be the most representative technique for analysis and modelling the complex DM knowledge. As for the repository, the DMM-based structure is envisaged to be the most appropriate one as not only does it collect all the essential and relevant DM constructs, but also because these constructs relate to each other in a way that they facilitate a better decision making mechanism.

Phase 2, knowledge analysis framework development. The initial knowledge analysis framework is constructed. Initially, these following seven ABMs are used, namely: *goal model, role model, interaction model, organisation model, environment model, agent model* and *scenario model*. The seven ABMs are used to provide constructs as containers for the DM knowledge. These constructs guide the analysis and modelling activities. A semantic mapping between the constructs of the ABMs and the constructs of the DMM-based repository is developed. The mapping is also supported by the MOF framework to delineate the scope of the DMM construct (e.g. for action at *M0* or policy at *M1*). This process helps to disentangle the fuzzy and overlapping of concepts across the DM phases. A generic ABM metamodel, FAML (Beydoun *et al.*, 2009a), is utilised to map ABM constructs to DMM constructs. It is the most generic available AOSE metamodel. FAML constructs augment corresponding constructs of DMM. There are fewer FAML constructs than DMM constructs. I.e. there are some concepts in each DM phase that are annotated by the same AB concept. Hence, one-to-many (or many-to-one) relationships in the transfer process routinely arise. A DM expert from the agency where the case studies come from is engaged to supervise the process. The expert identifies the most plausible DMM constructs for a particular ABM construct, guiding the transfer process. The transfer process is well supported by a tool that imports the ABM constructs (in XML) into the repository (built using a database system). The tool is essentially the instantiation of the framework created. The tool is aimed to, not only demonstrate that this framework is implementable but also to facilitate a user-friendly interface for the framework evaluations undertaken in the subsequent phases of the research.

Phase 3, internal framework evaluation. The aim is to evaluate the effectiveness of the developed framework. This evaluation is performed by validating the framework with a case study obtained from the flood DISPLAN of the Wagga-Wagga SES NSW. While the initial evaluation successfully shows that the framework works as it is intended to, it highlighted deficiencies in the initial version of the framework: 1) the generalisability issue where the objective of the framework is to be used by as wider as possible the stakeholder to develop their

DM resiliencies. In other words, for the same type of disaster (e.q. flood, bushfire), other stakeholders have to 'reinventing the wheel' the analysing and modelling their ABMs from scratch before transferring the models into the repository. Thus, instead of the unique plan (in the initial evaluation is the Wagga-Wagga Municipality SES of flood DISPLAN), the use of flood DISPLAN template of the SES NSW as the input of the framework is stipulated to adapt the ABM models to the DISPLANS before the analysis of any plan begins. To further improve the speed of the analysis, the analysis process is changed to become depth first. The analysis of each agent goal is pursued in a depth first manner. This reduces the number of revisits of sections within the plan. To confirm the efficacy of these improvements, a case study of another flood DISPLAN template of the SES NSW is utilised in the next phase.

Phase 4, external framework evaluation. This phase includes two case studies (Chapter 6 and Chapter 7). The flood DISPLAN template of the SES NSW is used as the input for the framework to confirm the two enhancements identified from the internal (initial) evaluation. The ABMs of the Wollongong SES flood DISPLAN is generated out of the customised ABM templates of the SES NSW. Eventually, the Wollongong DISPLAN is then transferred into the repository. The depth-first approach clearly leads the process to become quicker and more effective. This is because the approach guides the knowledge engineer not only "where" to start but also "how" to do the customising process in detail. In addition, this approach also presents opportunities for multiple stakeholders involved. This can potentially make the customising process to be yet more efficient. A post-evaluation is also conducted by engaging the DM expert from the SES NSW. In the post-evaluation, it was clear that the transfer process is faithful to the content of the original DISPLANs. Notwithstanding this success, the thorough evaluation in Chapter 6 also presents opportunities for further enhancements. The evaluation shows that one of the ABM templates (the *agent model*) can be removed from the process without any loss of constructs, as all the constructs in that template are also available in another template. The evaluation in Chapter 6 also showed that some knowledge elements require additional information to make them operational at level *M0*. Such elements need to be instantiated from additional external sources (DM experts or additional documents). Chapter 7 explores these enhancements and also uses a template and a DISPLAN from SES Victoria (instead of the SES NSW) to also reduce any generalisability threats. The Moira Shire is the Municipality generated from the customised ABMs of the flood DISPLAN SES Victoria. The evaluation shows successfully that the use of only six ABMs (instead of seven models previously identified in the initial framework development) can fully represent the complex knowledge of the DM domain. In addition, the evaluation in Chapter 7 also shows that the use of external knowledge sources facilitates the more complete knowledge element structured in the ABMs, which subsequently enriches the knowledge managed in the repository representing the local characteristics.

8.2 Research Contribution

The thesis addressed a serious gap in DM knowledge analysis which also has been a hindrance in its reuse. Reuse of DM knowledge is essential to benefit from the painful disaster experiences when preparing and responding for future ones. This concern is not new. What is new, is addressing the complexity involved in the analysis using a systematic process that combines a number of complexity management conceptual tools: agent based modelling, MOF, and metamodel transformations. Bringing these powerful abstractions in combination, produced a systematic process to codify DM knowledge in a way to facilitate reuse. The codifying mechanisms address inherent complex features of the DM domain. Furthermore, the use of agent based modelling templates ensures that the systematic process is easily accessible by non-software analysts e.g. DM experts who are able to apply the process without the need for modellers support. In other words, the complex knowledge can recodified from the plans by the decision makers themselves. The thesis produced two tools that were used in this, one to support the agent based modelling and another is the DM repository. Both proved easy to use by DM experts. The repository produced was a prototype. To fully validate such a repository, all plans will need to be converted and DM decision makers will need to deploy the repository during DM activities. Clearly, this goes beyond the remit of this PhD thesis.

Various efforts have been devoted in modelling DM domain using ABMs. However, this work is the first in adopting ABM in a descriptive fashion to analyse and model the complex DM knowledge to subsequently transfer it into a knowledge repository. The ABMs that are tailored together with the MOF framework are capable to disentangle the DM concepts from the DISPLANs. The MOF framework frames the concepts from the ABMs formulating how they are deposited in the DMM-based repository. In other words, the MOF framework bridges the abstract constructs in the DMM repository and those in the ABMs. In some cases, an agent construct points to multiple DMM constructs. Resolving such cases requires DM expert mediation.

The developed framework also demonstrates its capability to extract knowledge elements from the DISPLANs and position these elements semi automatically in the repository. Using MOF the positioned of the elements along the DM timeline is also identified. This is particularly important for decision-making, planning/policy and responding to real world events. Stakeholders with various roles in the PPRR DM framework can be guided by the essential and relevant knowledge. The various artefacts constituting the framework are evaluated rigorously as per the DSR methodological cycle. Part of this evaluation, post-evaluations conducted by DM experts confirmed the benefits, useability and accuracy the knowledge structures in the repository. The experts affirmed that the repository is able to accurately inform the stakeholders in creating their story telling for decision-making mechanisms in the DM activities.

In addition, this thesis also contributes to AOSE by introducing a depth-first approach in the analysis and modelling activities. Specifically, this approach enables the analysis and modelling activities to be undertaken concurrently. In other words, this analysis and modelling process can be performed more efficiently by the involvement of many stakeholders simultaneously. This approach shows "*how*" to do the analysis and modelling activities in detail.

Notwithstanding the successful development and evaluations, some concerns are identified to set another improvement for a future research direction. These concerns are elaborated further in the following section.

8.3 Research Limitations for Future Research Directions

Chapter 7 presented the final version of the knowledge analysis framework. The framework was shown to be successful to meet the research objectives of converting DISPLANs to a unified representation, efficiently and effectively. Nonetheless, some limitations are worth noting. These are outlined in what follows with concomitant possible future research extensions.

Firstly, the final version of the framework is not a fully automatic process. In a case that there are more than one representative concepts in the repository where an ABM can be mapped with, a DM expert intervention is needed to decide the plausible mappings. Future research will consider automating some of this effort to eventually replace the expert. A concomitant learning process can be considered to initially learn from the expert. This will likely require imposing further structures and annotations on the source of knowledge, the DISPLANs. This can then pave the way for either of two possibilities: Natural Language Processing (NLP) techniques e.g. for the formalisation or estimation of the similarity measures between the concepts in the ABMs and those in the repository. Mathematical formulation and or ontology semantic mediation/integration will be required to varying level of degrees in both approaches.

Secondly, in the modelling process, one of the knowledge elements representing that needs to be analysed and modelled appropriately into the corresponding ABM is a time-sensitivity characteristic. It is the knowledge element that describes agent is situated in an environment therefore it will be reacted to. This time sensitivity is not reflected in the original plans, However, the transfer process highlights where it can be represented. Agent models highlight where the <<*trigger*>> concept can apply (to some actions). Namely, the *scenario model* itself can have

<<*activity*>> and associated <<*trigger*>>. This will require additional concepts in DMM and additional input from the DM expert (or external sources).

Thirdly, although the evaluations showed that the framework works as intended and addresses the research objective, all the case studies are about one particular event, the flood disaster. For the future research direction, utilising other than flood disaster types, other category (e.g. bushfires, landslides, etc.) and can be sought for further evaluations. Further evaluations from other countries would also be valuable. This will ensure that the framework can also work as effective and efficient as with the flood disaster in the Australia. Finally, to be able to evaluate the effectivity of the framework in the real DM activities, the framework needs to be employed by the DM practitioners in real situations. This is another future research direction.

It is worth noting that in all the evaluations of the framework, both internal and external, all the knowledge elements in the DM documents were successfully codified into the repository. The processes involved were supervised by DM experts whose feedbacks were consistent and there was no semantic discrepancies. This consistency is not too surprising given that the case studies involved experts with similar DM training in flood management in Australia. Further evaluations using different case studies from other countries and conducted by a wider variety of experts are certainly worth flagging for future studies.

8.4 Concluding remarks

This thesis has successfully developed and validated the knowledge analysis framework in the DM domain. This is based on the serious gap identified and discussed in the literature review. ABM has demonstrated as the most representative paradigm in representing the complex DM characteristics. DMM adopted in this thesis, not only, proved as an effective basis for a representative repository to deposit the knowledge of the ABM, but also guided the identification of the related relevant and essential of DM knowledge in performing the DM activities. The innovative deployment of MOF was key to provide a semantic bridge and interoperability of the transfer process between the ABM and the repository.

The thesis supports the DM resilience endeavours. In particular, it presents new opportunities to make DM knowledge more accessible and searchable supporting more effective decision making processes.

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Appendices

Appendix A

User manual guide of Knowledge System for Disaster Management tools

To be able to use the tools developed to evaluate this thesis, there are two things that need to be prepared: (1) preparing the web-based environment to run the tools; (2) running disaster knowledge management tools. They both are elaborated as follows:

1. Installation

There are 3 (three) applications that need to be installed:

1. Web server; we use Apache web server as a server where all the web files will be placed.
2. Database server; MySQL is the database server to store all the knowledge.
3. PHP; a server-side scripting language to allow request from the web to the database.

Fundamentally, each of these packages can be installed separately. However, for the efficiency (yet effective), we use a bundled version that contains three packages in one, called: ***Wampserver***.

1.1. Installation steps:

1. Check if your machine is a 64-bit or 32-bit architecture: ***Window start > control panel > system***

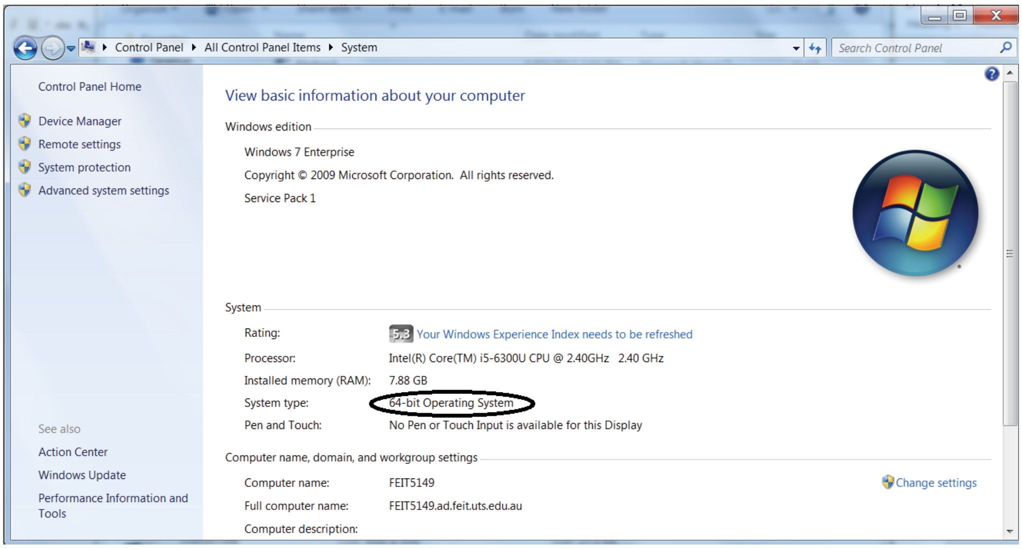

Figure 1 Checking the machine architecture.

2. Check also if you have administrator right to install the software in the computer you use.
3. Get the package. You can get the most up-to-date package from internet, for instance through this link: http://www.wampserver.com/en/ or available from the cd coming with the thesis.
4. Download or copy the suitable package based on your machine architecture (x32 or x64) to your local hard drive, for instance into folder: ***C:\Downloads***.
5. Double click to start the installation.
6. Follow through the instructions until finish. Once it is done, under your ***C:*** directory, you will have ***Wampserver*** folder: ***C:\wamp***.

1.2. Testing server configuration

Testing is aimed to see whether the web server supported by MySQL and PHP has been configured into your machine with these steps, as follows:

1. Open your default web browser. As configuration we adopted in the development stages, the tools will appear better using google chrome browser. If you do not have that, you can use your default one.
2. Type: ***localhost*** in address bar of your browser. A server configuration information will appear:

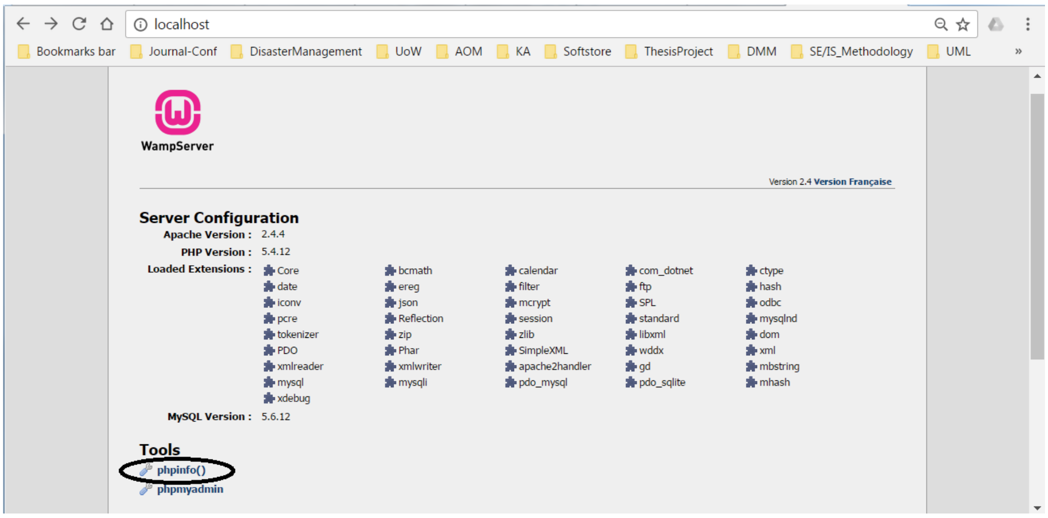

Figure 2 Server configuration in phpinfo().

3. Check whether the package PHP and MySQL have been set up is by clicking: ***phpinfo()***.
4. Go through all the configurations and check whether you have those packages. If yes then Congratulation!! Now you have a local web hosting supporting PHP and MySQL, :).

2. Disaster Knowledge Management tool

This section will show how to use the tool as an embodiment of the developed framework. Essentially, there 2 (two) applications (1) analysing and modelling ABMs; (2) knowledge system for disaster management itself. However, before using these tools, a database configuration and file management need to be prepared:

2.1. File management

As mentioned, there are two tools developed separately and managed in different folders, namely ***aoa26*** and ***dm1*** folders. The ***aoa1*** is about the analysing and modelling files using ABMs and ***dm1*** is the knowledge system for disaster management files. These two folders need to be copies into the web server under the root folder, as follow:

1. Go to the CD room. You will find these two folders: ***dm1*** and ***aoa26***.
2. Copy and paste them under root folder of your local web server: ***C:\wamp\www***.

2.2. Initial testing the tools

Once those two tools are copied into your local root folder, the first that need to be done is testing them.

1. Go to your browser.
2. In the address bar, type: ***localhost/dm1***.

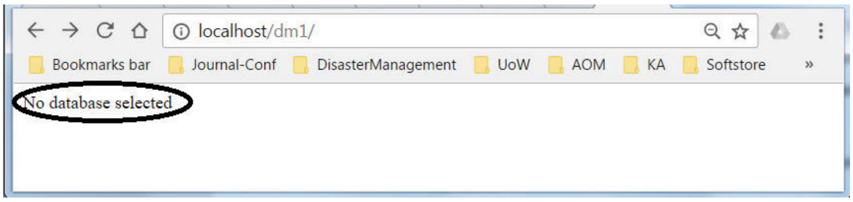

Figure 3 No database selected.

As can been from Figure 3 that there is no database selected. This means that the database needs to be setup to be used the tools.

2.3. Database setup

As benefits using the bundled package ***wamp*** is that it comes with various additional tools. One of them is MySQL database web management. This helps non-expert user to manage database relatively easy. Configuring the database using the ***phpmyadmin*** follows these following steps:

1. Go to main page of the server configuration by typing ***localhost*** from your web browser address bar. This is shown in Figure 4.

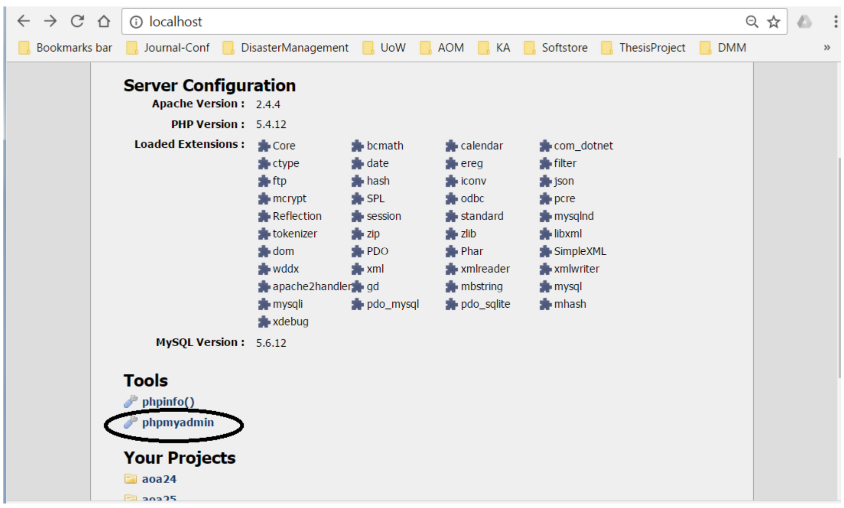

Figure 4 *Phpmyadmin* link.

2. Select ***phpmyadmin***.

3. As can be seen from the appeared window, there are 4 (four) default database schemas in MySQL: ***information_schema, mysql, performance_schema, test***. To import the new schemas for the tools, select tab ***import***.

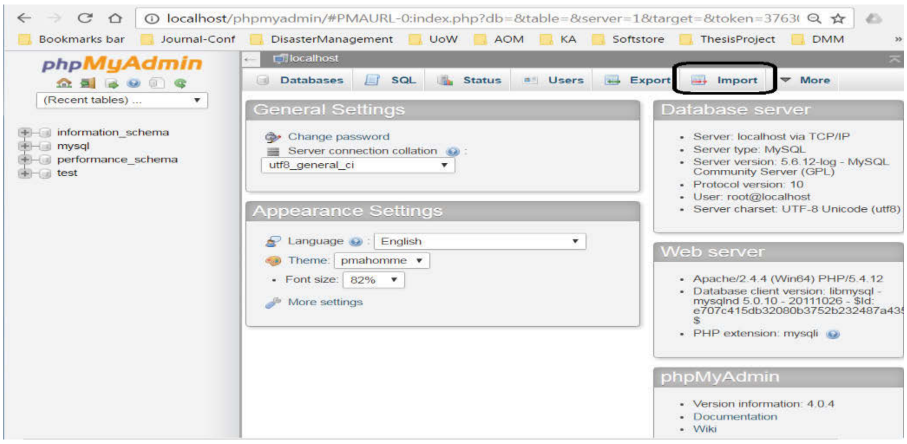

Figure 5 Importing tab.

4. Select ***choose file*** button to locate the SQL files needed. The SQL files are in the SQL folder is under SQL folder in the dm1 folder: ***C:\wamp\www\dm1\SQL***

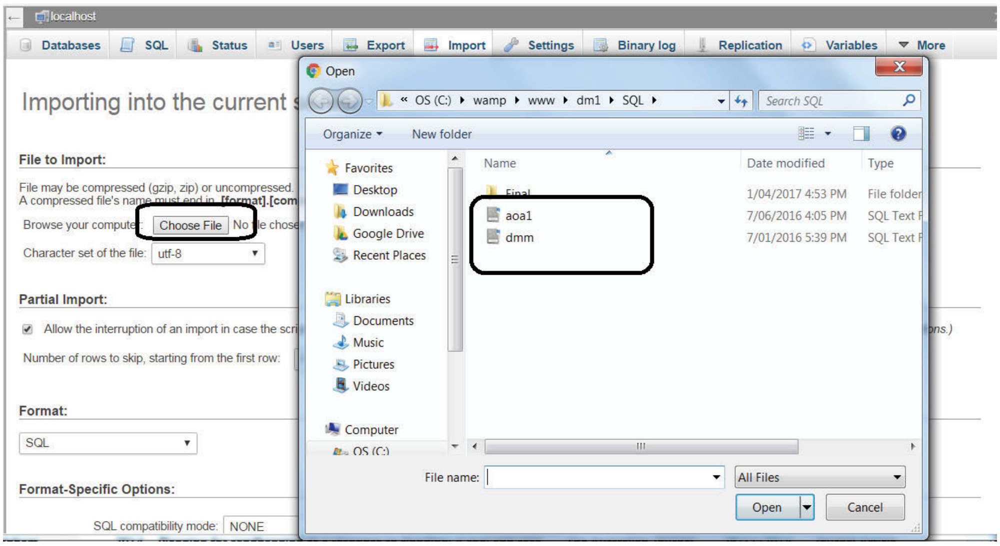

Figure 6 Choosing files to be imported.

5. Select ***dmm.sql*** first and select ***go***.
6. Once the import is success, the ***dmm*** schema is automatically listed in the left column, as shown in Figure 7.

Figure 7 Imported knowledge elements of the DMM and ABMs into the database.

7. Repeat from step 4 to import ***aoa1.sql***.
8. Once both schemas have been imported to the database, the next is to test again the tools.

2.4. Testing the tools

1. To test the *agent-oriented analysis tool*, go to address bar and type: ***localhost/aoa26***. If the window appears as Figure 8 then it works, congratulation!!

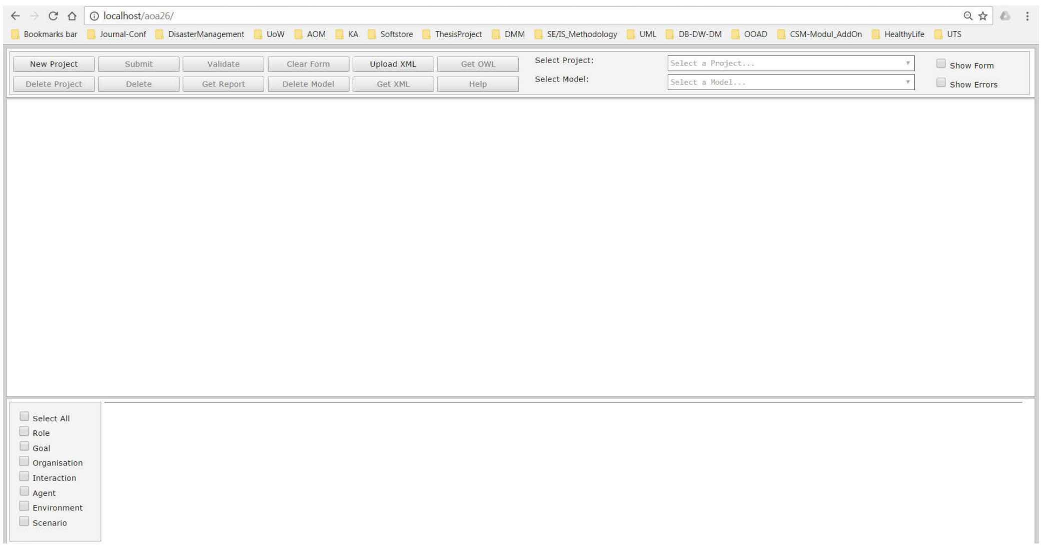

Figure 8 Agent-oriented analysis interface.

To test the *knowledge system of disaster management tool*, in your address bar, type: ***localhost/dm1***, if the appearance is similar with as in Figure 9 then congratulation it works.

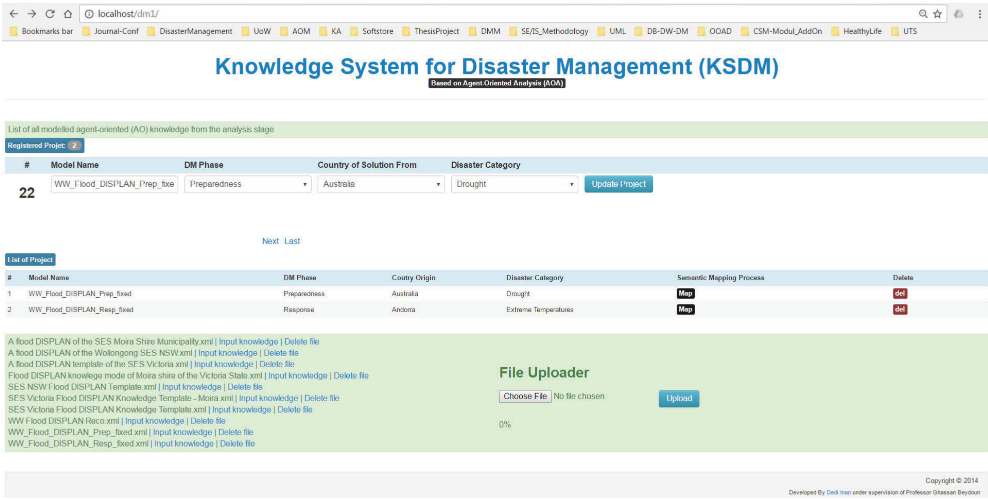

Figure 9 Disaster knowledge management interface.

3. Agent-Oriented Analysis tool

This tool is used in the analysing and modelling knowledge elements out of the DISPLAN and laying them down in the corresponding 7 (seven) ABMs. It starts in a row: *goal model*, *role model*, *organisation model*, *interaction model*, *environment model*, *agent model* and *scenario model*. In what follow, the analysing and modelling each of these models are shown:

<u>Goal model</u>

1. Go to: ***localhost/aoa26***.
2. Create a new project and enter the project name, for instance, ***SES NSW flood DISPLAN template***. Note that the feature of the developed framework allows us to model the entire DISPLAN template in one project or we can focus to only a main goal at a time. At the end, all separately analysed and modelled ABMs will be combined together in the repository to form a 3D structure. See Chapter 6 for this example.

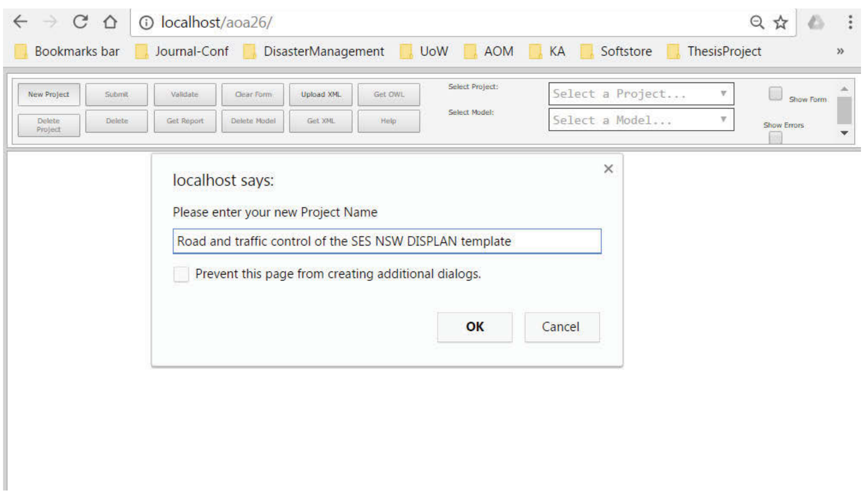

Figure 10 Creating and naming a new project.

As each goal (main goal and sub-goal) has at least 1 (one) role that responsible for, there should be at least one role that is available to proceed the *goal model*. Once a role model is created, the goal modelling is continued.

3. Creating a role in *role model*, for instance: <SESLN> SESLOC. As XML syntax using the same bracket, in the tool, it is typed as : --SESLN-- SESLOC.

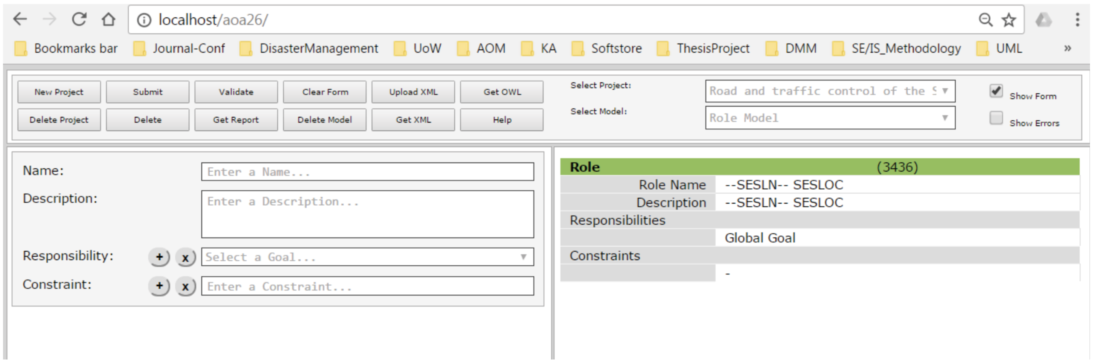

Figure 11 *Role model* interface.

4. Go back to the *goal model* and complete the analysing and modelling that particular main goal template. Figure 12 shows the example.

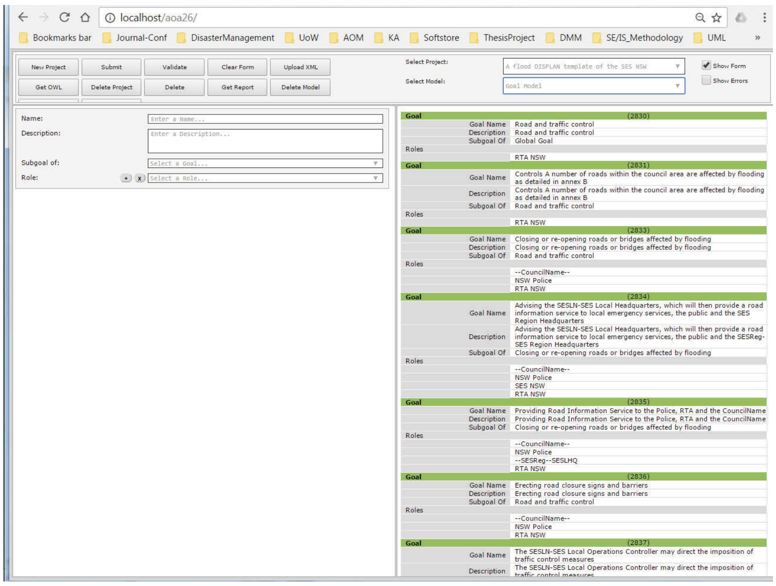

Figure 12 Analysing and modelling *goal model* interface.

Role model

1. Go to *role model* tab.
2. Filling out all the fields with appropriate knowledge elements or leave it with a mark " – " if there is no, for instance, for the *constraint* element. Complete the *role model* as shown in Figure 13:

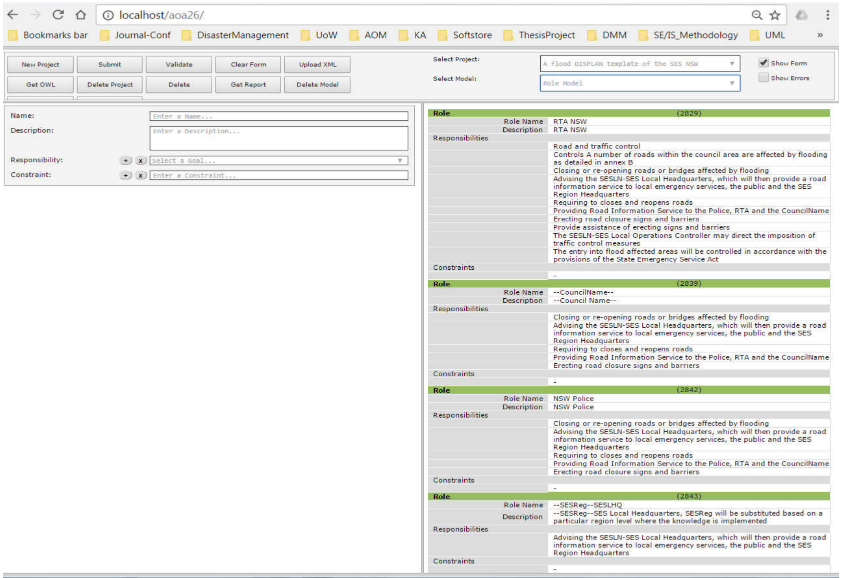

Figure 13 Analysing and modelling *role model* interface.

Organisation model

Go to organisation model tab.

Complete this model with the corresponding knowledge elements, as shown in Figure 14.

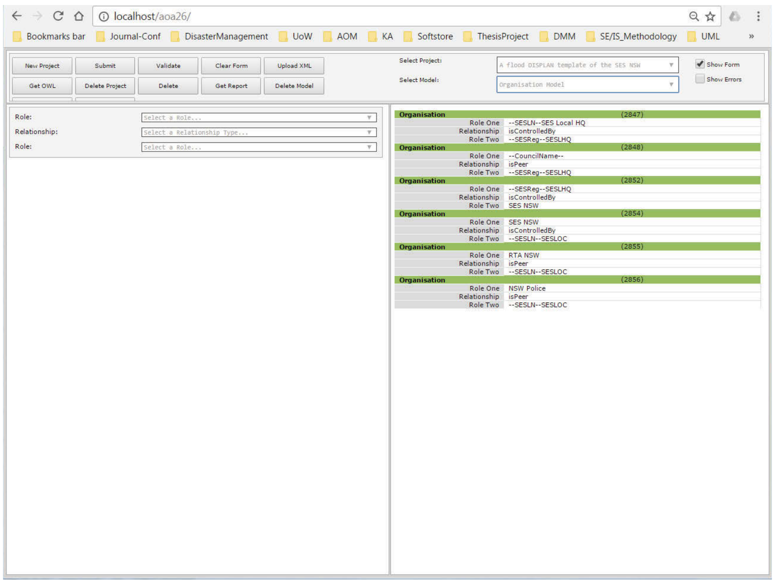

Figure 14 Analysing and modelling *organisation model* interface.

Interaction model

Go to *interaction model* and complete it as shown in Figure 15:

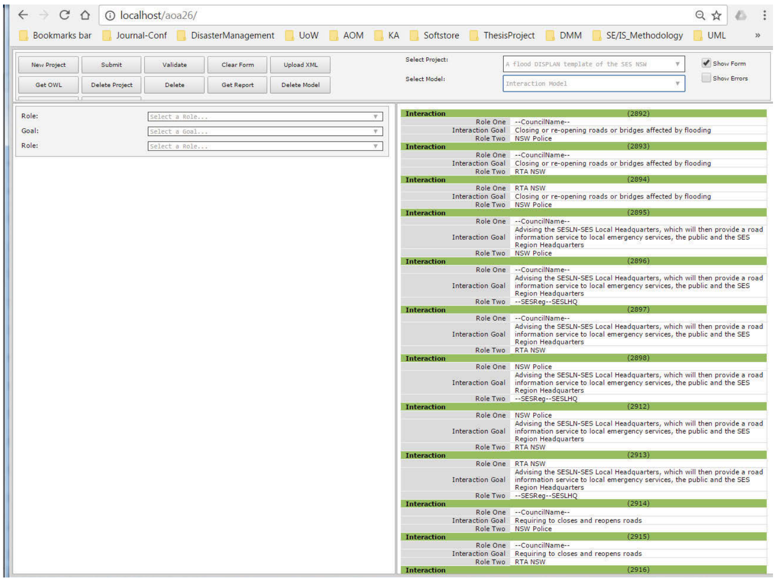

Figure 15 Analysing and modelling *interaction model* interface.

Environment model

Complete this model as shown in Figure 16:

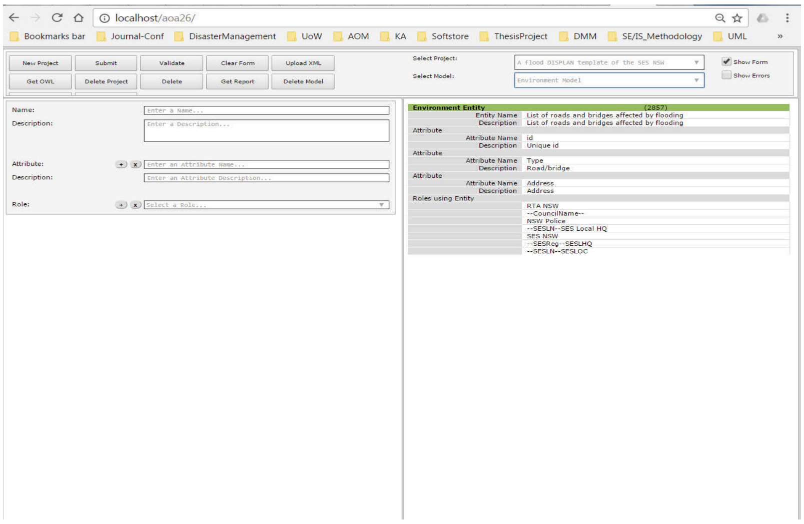

Figure 16 Analysing and modelling *environment model* interface.

Agent model

Complete this model as shown in Figure 17:

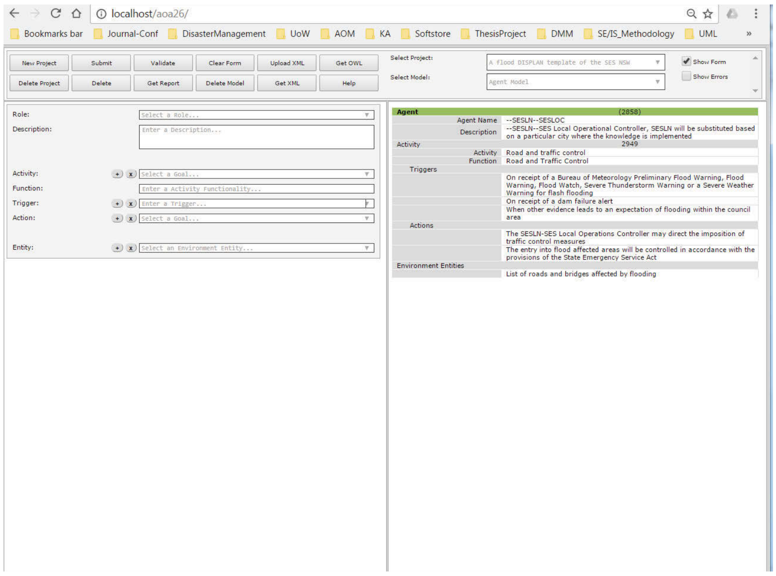

Figure 17 Analysing and modelling *agent model* interface.

Scenario model

Complete this model as how it is done in the previous models.

3.1. Generate a particular flood DISPLAN based on the template

Once the DISPLAN template of ABMs is in place, the next is to generate a particular flood DISPLAN. In this case, it is a Wagga-Wagga flood DISPLAN. To do that:

1. Go to the proxy folder where the template files is: ***C:\wamp\www\dm1\uploads***.
2. Make of copy of it and rename it to be: ***Wagga-Wagga SES NSW flood DISPLAN*** or any name you prefer.
3. Go back to the agent-oriented analysis tool and substitute all the knowledge element classes with elements of Wagga-Wagga Municipality.

3.2. Get the XML file

Once the seven ABMs are done, the next to be done is importing the knowledge elements structured in these models into the MySQL database. These elements of the seven ABMs are stored in one XML.

Select the ***Get XML*** button to get it. The file by default will be downloaded into the download folder.

4. Knowledge System for Disaster Management

To be able to import the XML file into the database, follow those steps:

1. Go to the address bar and type ***localhost/dm1/***.

2. In the *File Uploader* section, click ***Choose File*** (1) to locate the file and followed by clicking the blue ***Upload*** (2) button afterwards. In this stage the file ***Wagga-Wagga SES NSWS flood DISPLAN*** (3) is moved to a proxy folder that is ready to be imported.
3. Click the link ***Input Knowledge*** (4), next to the file that was just imported to put the all the knowledge elements in the managed in the XML file into the database. Once it is done, the knowledge now is on the database as shown in (5).
4. To change the name of the knowledge, phase DM, country of the knowledge from and the disaster category, go to (6) and press (7) to execute the changes.
5. Now, go to the knowledge mapping process by clicking (8).

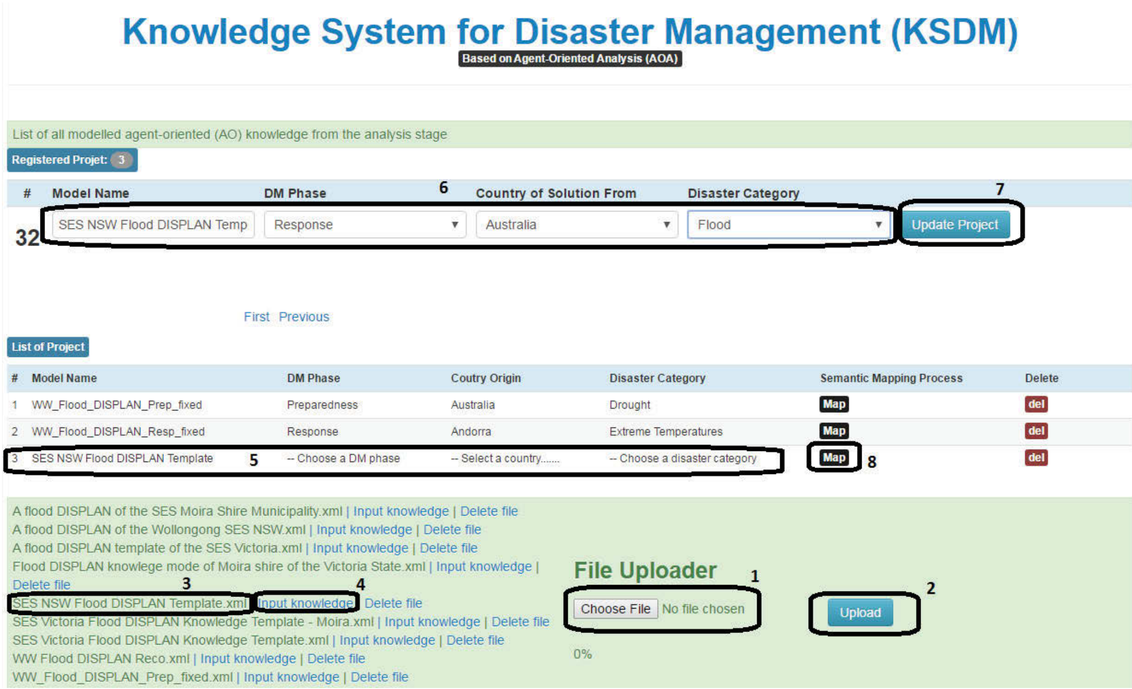

Figure 18 Importing the XML DM knowledge elements interface.

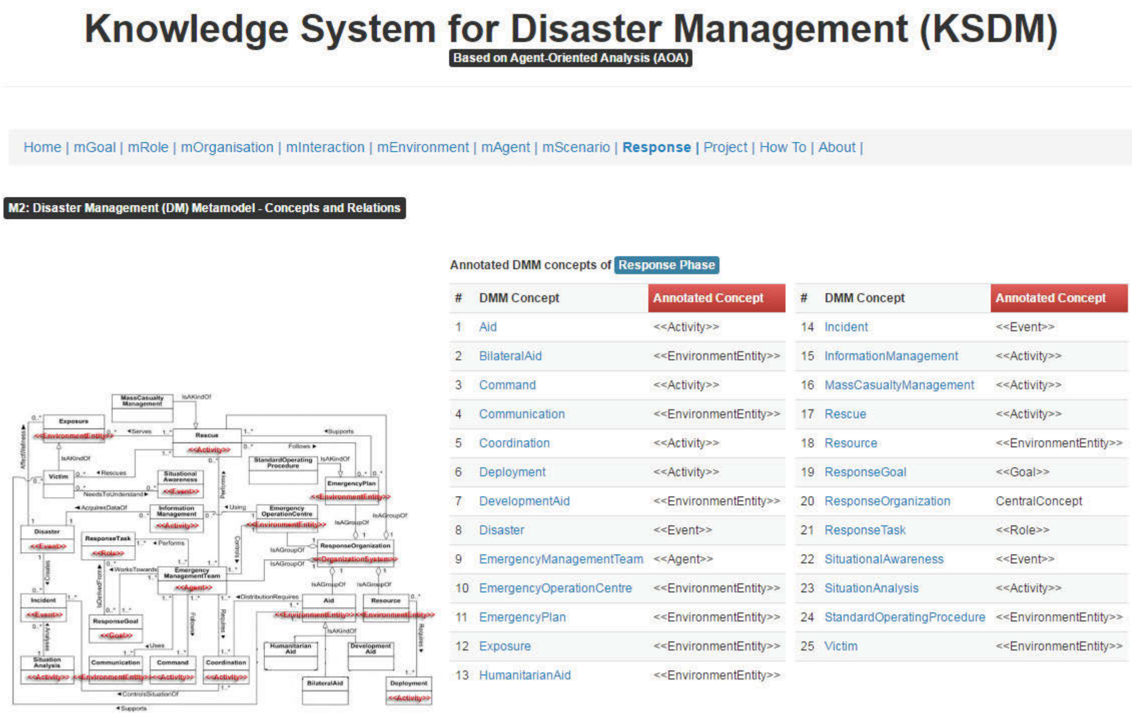

Figure 19 Annotated concepts of the DMM-based repository.

Mapping the goal model

As there is only one goal model being represented in the repository that is the *ResponseGoal*, the mapping process is mapped with it.

Click the ***Update record*** button to apply the change.

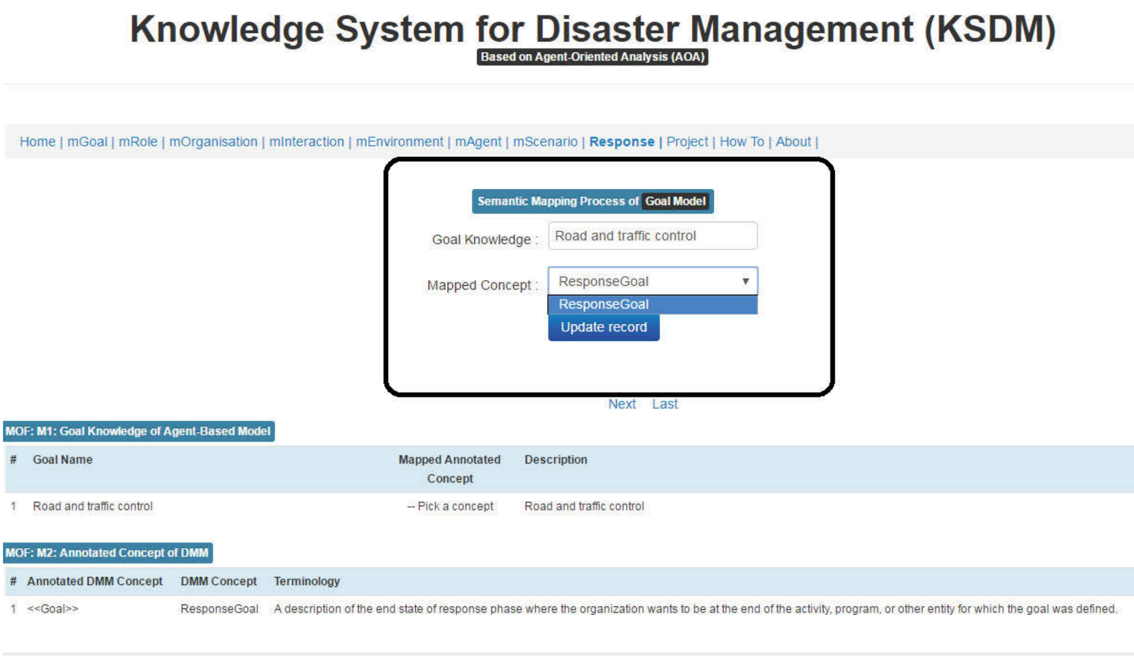

Figure 20 Mapping the *goal model.*

Mapping the role model

As there is only one possible concept that matches with the typical role knowledge from the *role model*, the mapping process between the role concept in the repository and the role knowledge are proceed directly.

Mapping the organisation model

Organisation model is modelled in the *role model* at once as the knowledge elements are from.

Mapping the interaction model

Interaction model is modelled in the *role model* and *goal model* at once as the knowledge elements are from both of them.

Mapping the environment model

Unlike the previous models, there are more than one possible concept representing the environment typical knowledge. Thus, the knowledge engineer selects the most appropriate one to be mapped with. This is as shown in Figure 21.

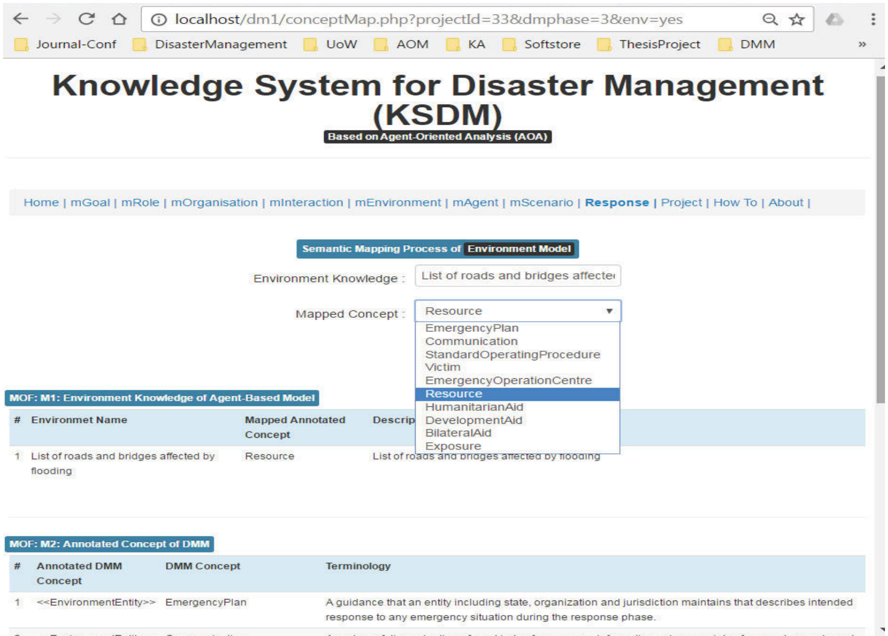

Figure 21 Mapping the *environment model.*

Mapping the agent model

Mapping the *agent model* is similar as one of the *role model*. This is because there is only one possible concept representing agent in the repository.

Mapping the scenario model

Mapping the scenario model is as in the environment model as there is more than one concept representing scenario knowledge in the repository.

5. Creating the timeliness story telling of DM

Once all the mapping processes of the knowledge elements in the ABMs and their corresponding concepts in the repository have been plotted, the final stage is to create a story telling of the DM scenario being framed in a timeline. The knowledge elements for a particular time are presented comprehensively and holistically.

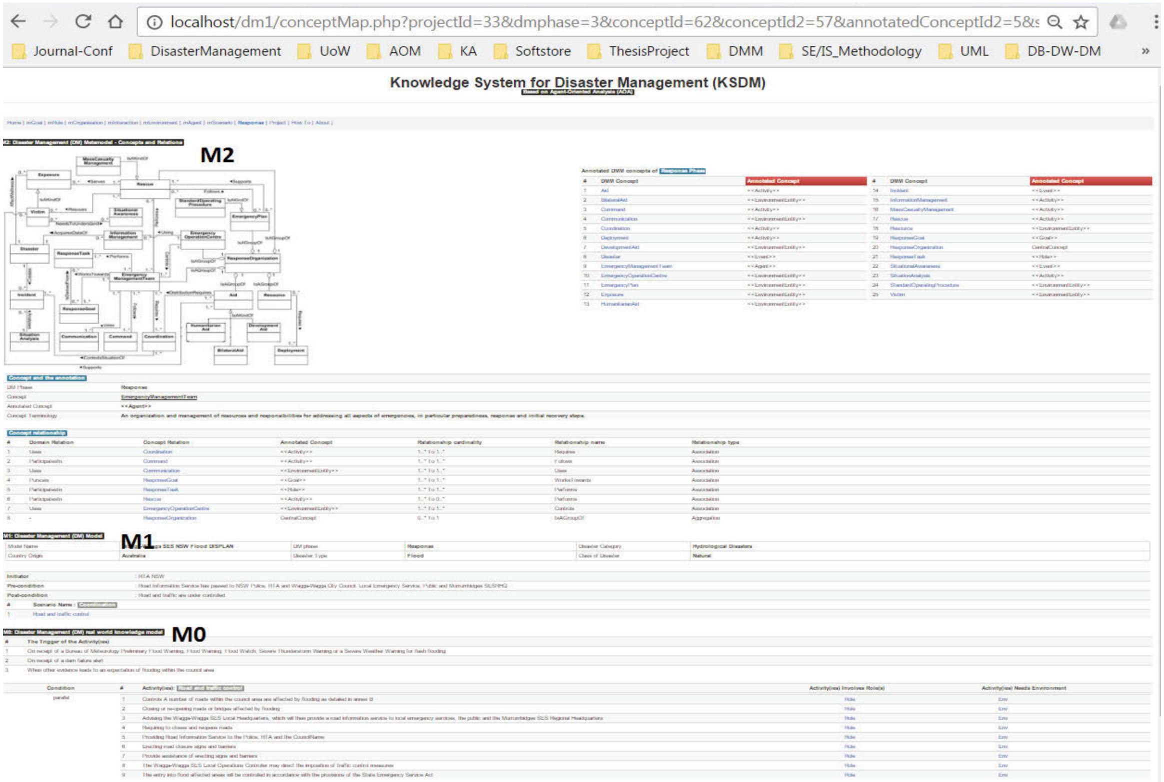

Figure 22 A holistic and comprehensive DM knowledge structure in annotated DMM-based repository.

Developing a story telling being framed in a time line is first begun in the decision making level concepts, they are in *M2* level.

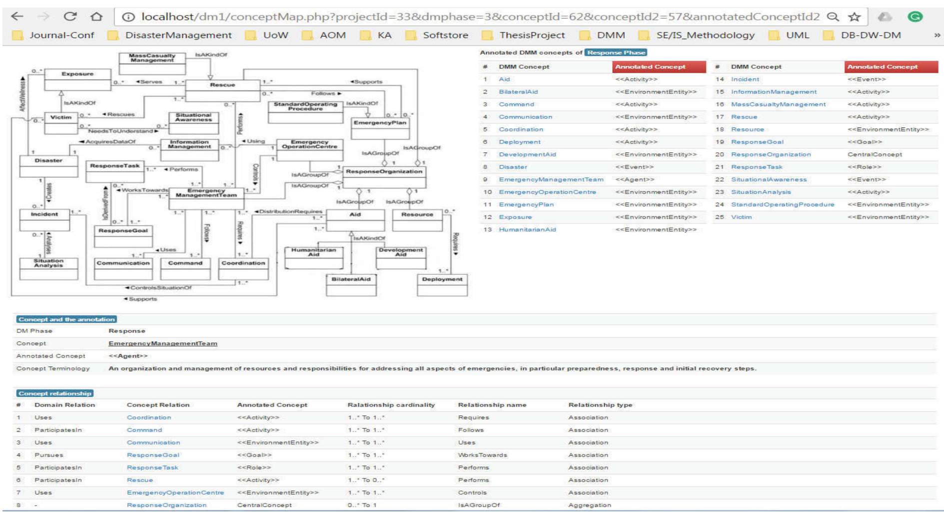

Figure 23 Knowledge structure in *M2* layer.

Choose a scenario concept to see the relation the concept to others and the knowledge of that particular concept in the lower level, *M1* and *M0*. For instance, from the example presented previously, coordination concept is the activity to be drill down into the lower level comprehensively and holistically. Figure 24 and 25 show the knowledge structure in *M1* and *M0*, respectively.

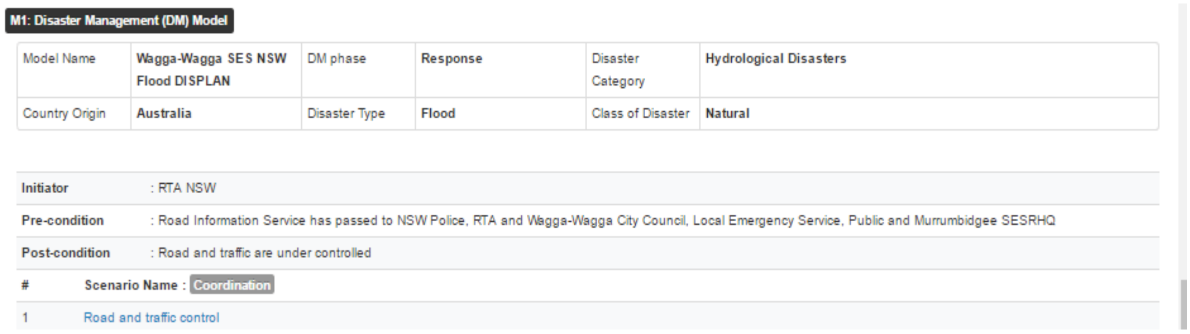

Figure 24 Knowledge structure in *M1* layer.

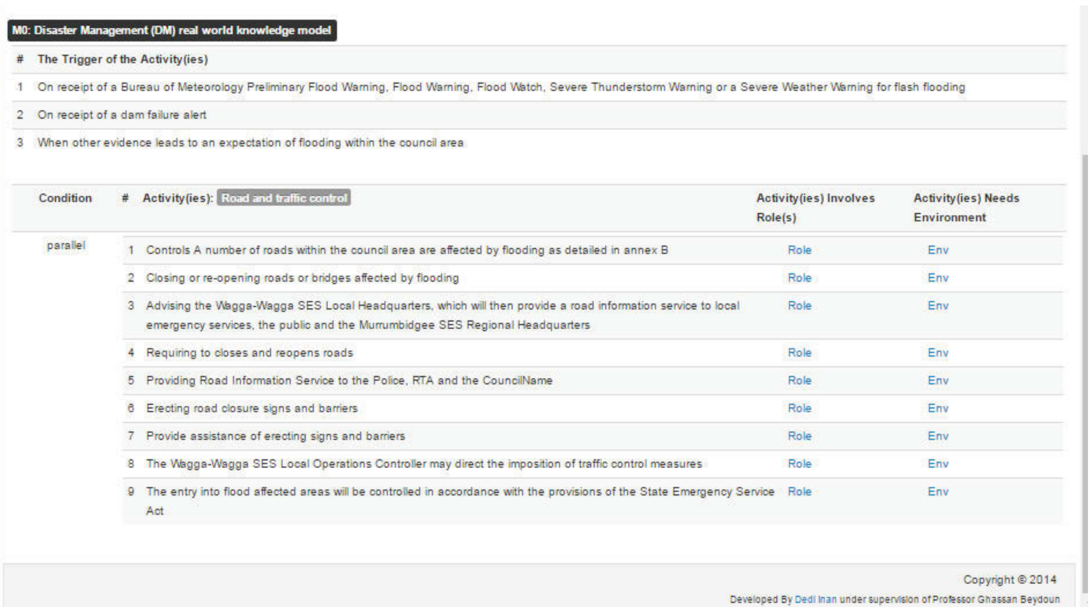

Figure 25 Knowledge structure in *M0* layer.

Appendix B

Semi-structure questionnaire for DM expert evaluation

Questions for the developed-framework evaluation[1]

[After presentation and demo the system]

1. A brief process introduction in the conceptual level

Following this is the brief explanation of the developed framework.

(a) The Agent-Oriented Analysis (AOA), the analysing and modelling the Disaster Management Plan (DISPLAN) knowledge template to produce the customized AB models; The DISPLAN knowledge template in the document is in the semi-structured formats based on the DM cycle: Prevention, Preparedness, Response and Recovery PPRR). This is obtained from the authoritative Disaster Management (DM) agencies. The Agent-Based (AB) models are the seven agent templates that have capabilities to capture the complex knowledge from document and structured them comprehensively. They are: the *goal model*, representing the objectives that need to be achieved by the roles involved in the activity; *role model*, informing the responsibilities of each role in the activities; *organisation model*, representing the hierarchy level knowledge of the roles played by agents where they need to communicate, negotiate and coordinate each other where they are from different jurisdictions; *interaction model*, elaborating in what extent roles are interacted each other; *environment model*; informing the resources used by the roles in pursing the objectives; *agent models*, listing all activities played by each role (played by each agent) that need to undertake in achieving the main goal, what trigger the activities and the *scenario model* representing the comprehend knowledge comprising the activities to be conducted by the roles, what resources needed to pursue them, the pre-condition of the activities, what is the post-condition after completing them, what trigger them, who is the initiator of the activity as they are a collaborative activity and are the activities undertaken parallel, interleave or sequential. These later can be transformed into other formats for other development purposes, for instance, Information System Development, Knowledge-Based System and so forth. The Meta Object Facility (MOF) from the software engineering domain is the other element in this stage used to disentangle the interwoven and fuzziness knowledge. The MOF lend itself to represent the knowledge holistically. It helps the stakeholder to distinguish whether the knowledge is in the, planning or policy (M1) or in in the real world activity (M0) levels. All these elements are tailored together to analyse the document and producing the customized AB DISPLAN knowledge template;

(b) In the second stage, the customized AB models are transferred in to into its representative repository. The repository essentially is the knowledge represented in the conceptual level (M2). The transfer process basically is an intermediate activity between the knowledge from the real world activities (M0) to their representations in the conceptual level (M2). Both knowledge layers M0 and M1 are from the previous stage. This implies that whatever knowledge coming from the real world activities should have their representations in the repository. The repository should contain as complete DM concepts as possible. As it cannot be mapped directly from the M0 to M2 then we introduce M1 in the middle to facilitate the processes. In software engineering, this typical repository is a metamodel format. Therefore, we embrace a Disaster Management Metamodel (DMM) as our repository as it represents the complete concepts in the domain. As this is a knowledge-based modelling, then mapping the knowledge between the layers is conducted semantically. A DM expert is also required to mediate the process as for each of the knowledge from the DISPLAN there might be more than one concept where appropriate to be mapped to. Therefore an expert intermediate both knowledge and its appropriate concept by mapping them that have the similar semantic meaning. At the end, the stakeholder can trace

[1] The ethical approval of the project has been approved by Human Research Ethics Committee with ethics number: HE15/387, 30 October 2015.

back and forth each of the concept in the DMM to its corresponding knowledge in the real activities layer or otherwise.

[The questions might be developed during the interview as this is a semi-structured format. Again, these following questions will be asked only if the framework demo has been done]

2. Agent-Oriented Analysis

1. In the first stage, knowledge is captured and structured into the seven Agent-Based (AB) models. Each corresponding model represents the particular knowledge structure of a broader know-how of the document. With respect to the AB model used in this framework, does the knowledge's meaning remain the same between one in the models and in the document?

2. If the meaning is changed, is it related how the knowledge is analysed and structured in the models by a modeller or the model structures/attributes themselves need to be adjusted to represent the knowledge from the DISPLAN in a more effective way?

3. The MOF is used to disentangle the interwoven and fuzziness of the knowledge. The layers are the M2, M1 and M0. The M2 layer is the repository that contains the knowledge in the conceptual level, the M1 layer is the planning or policy knowledge layer and the M0 is for the real activities knowledge layer where the stakeholders can embrace the knowledge and react appropriately without any deductive thinking. As the knowledge is written in English, how do you see that this modelling process can also be conducted by users without having domain expertise?

4. How do you see the MOF used can help to disentangle the fuzziness and interwoven knowledge in the AB structure?

5. The structure of AB models with respect to the MOF informs the incompleteness knowledge elements from the DISPLAN. How do you see this will help the DM authoritative agency to improve and complete the DISPLAN?

6. As the input of the modelling process, we use the DISPLAN template instead of the specific instance. This is aimed to create a set of DISPLAN AB models that can be customized based on the specific resources and environment of a region. How do you see this might help the sharing and reusing knowledge effectively and efficiently?

3. Knowledge transfer process

7. In the second stage of the framework, was all the knowledge in the document fully transferred to the repository? If not what was omitted?

8. Is there any other knowledge from the document that couldn't be transferred to repository?

4. Semantic mapping processes

9. In the semantic mapping processes, a modeller intermediate each of modelled knowledge in the AB structure with its appropriate concept in the DMM-based repository semantically. Can these activities be mapped by a non DM expert given that the mapping process based on the semantic meaning?

10. In the mapping process, if there is only one annotated DMM concept in the repository then a modeller can be automatically mapped the related knowledge model to the concept. However, if there is more than one concept then a modeller needs to choose the appropriate one. Do you see the possibility that the knowledge model might appropriate to be mapped to more than once concept in the DMM-based repository?

11. Do you have any suggestion for improving the mapping process to be more automated in this context?

5. Knowledge retrieval

12. The DMM prescient the concepts in the DM. This informs the stakeholders the other concepts and relations to complete the knowledge. How do you see this might help the authoritative agency to restructure the DISPLAN to complete the knowledge?

13. Could the knowledge retrieval process be understood easily in a DM decision making process? If it couldn't, in which part it is not easily to be interpreted? Do you have any suggestion to improve that?

14. In term of effectiveness and efficiency of the sharing and reuse of knowledge, how do you see the system can be used in developing a DM resilient agenda?

15. How do you see the retrieval knowledge in term of informing the knowledge in each timeline of a DM activity?

16. Could you understand the retrieved knowledge comprehensively[2]? Holistically[3]? In a DM activity?

17. The structure of AB models with respect to the MOF informs the incompleteness and missing knowledge elements from the DISPLAN. How do you see this will help the DM authoritative agency to improve and complete the DISPLAN?

6. Suggestion for improvement the developed framework

18. Can decision making for a DM be improved using this framework?

19. What do you think are the strengths of this framework?

20. What do you think are the weaknesses of this framework?

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[2] In this context, it means all the related knowledge elements have been combined and retrieved as a complete and integrate one to make decision. This also in the context helping the stakeholder to create a story telling based on the integrated knowledge elements.
[3] In this context, it means the knowledge is shaped in a particular format which contains all knowledge elements where a decision can be retrieved from, instead of shaping them separately.

21. Do you have any other comments on aspects of the framework overall?

22. Do you have any suggestions for improving the developed framework?

23. Do you have any suggestion for improving the knowledge retrieval process? Or how does the knowledge structure help in decision making process?

Thank you for your participation in this study

Please improve each of the answers based on what you understood from our discussion. If it is required, I can capture the system and give a brief explanation what it means.

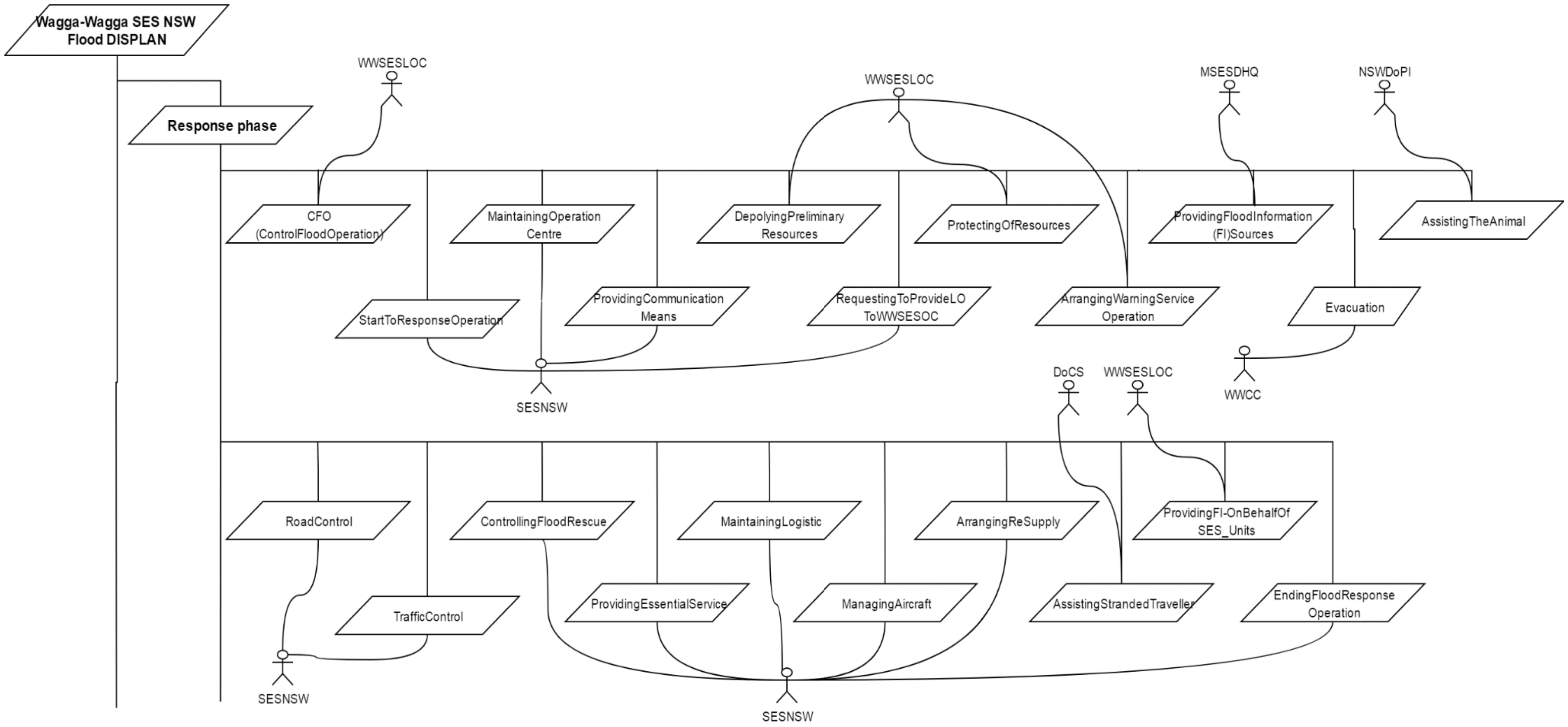
Appendix C

ABMs of the Wagga-Wagga SES NSW DISPLAN

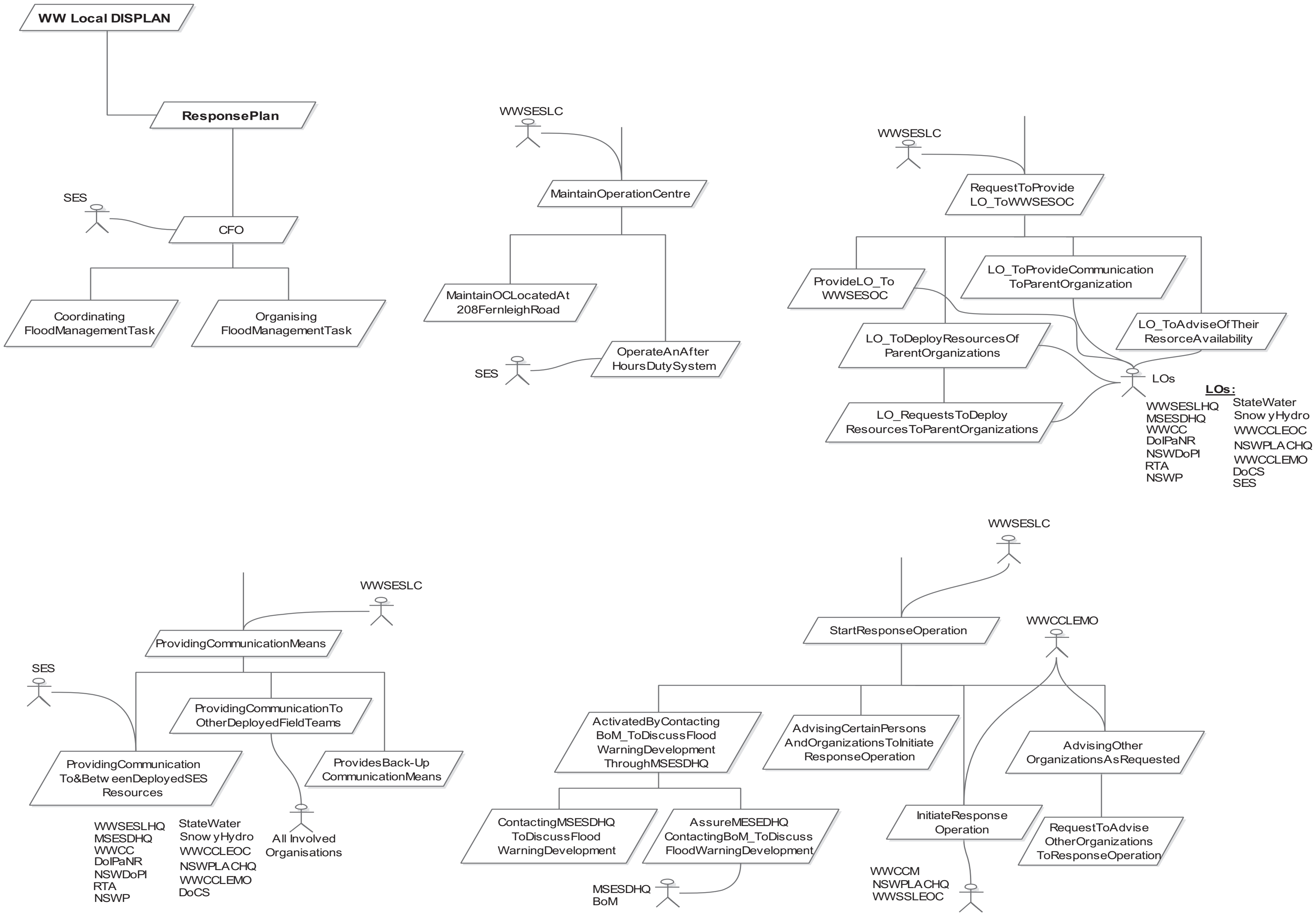
DM Plan	*Goal model* of the Wagga-Wagga SES NSW DISPLAN
Country	Australia
Disaster Type	Flood
Phase	Response Phase

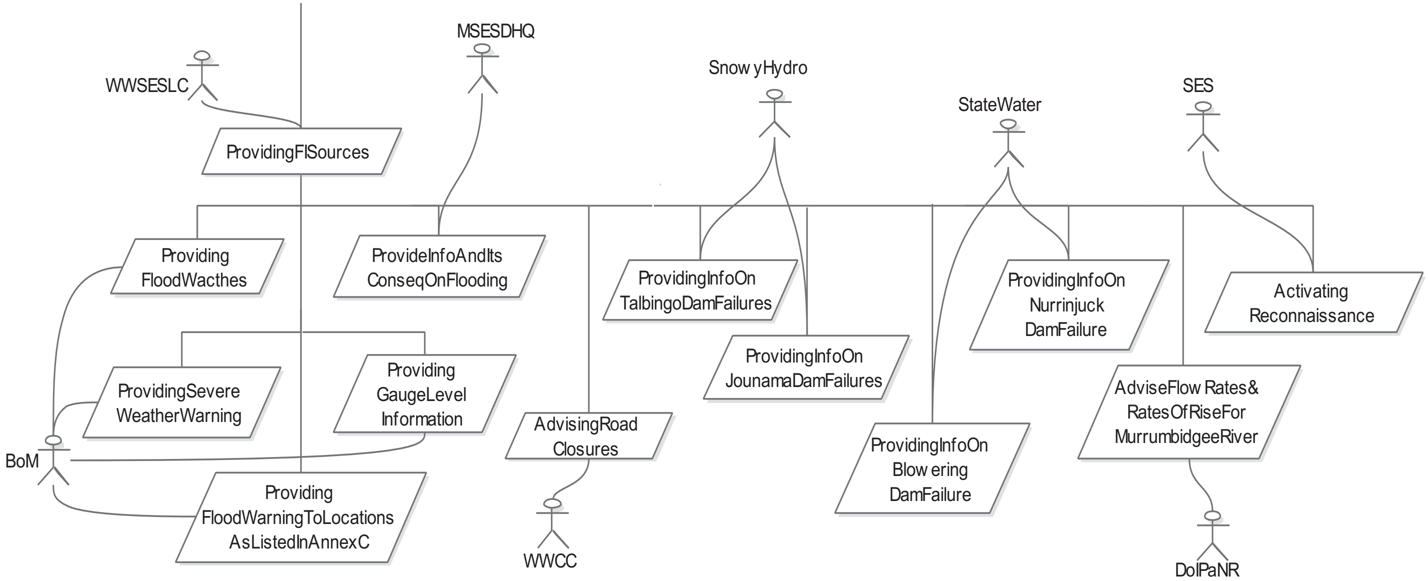
1. *Goal model*

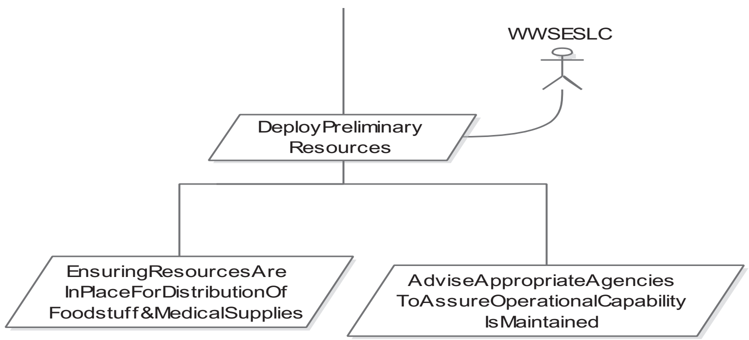
Main goals

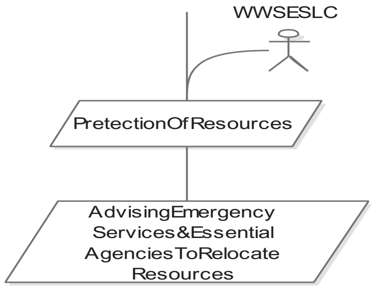


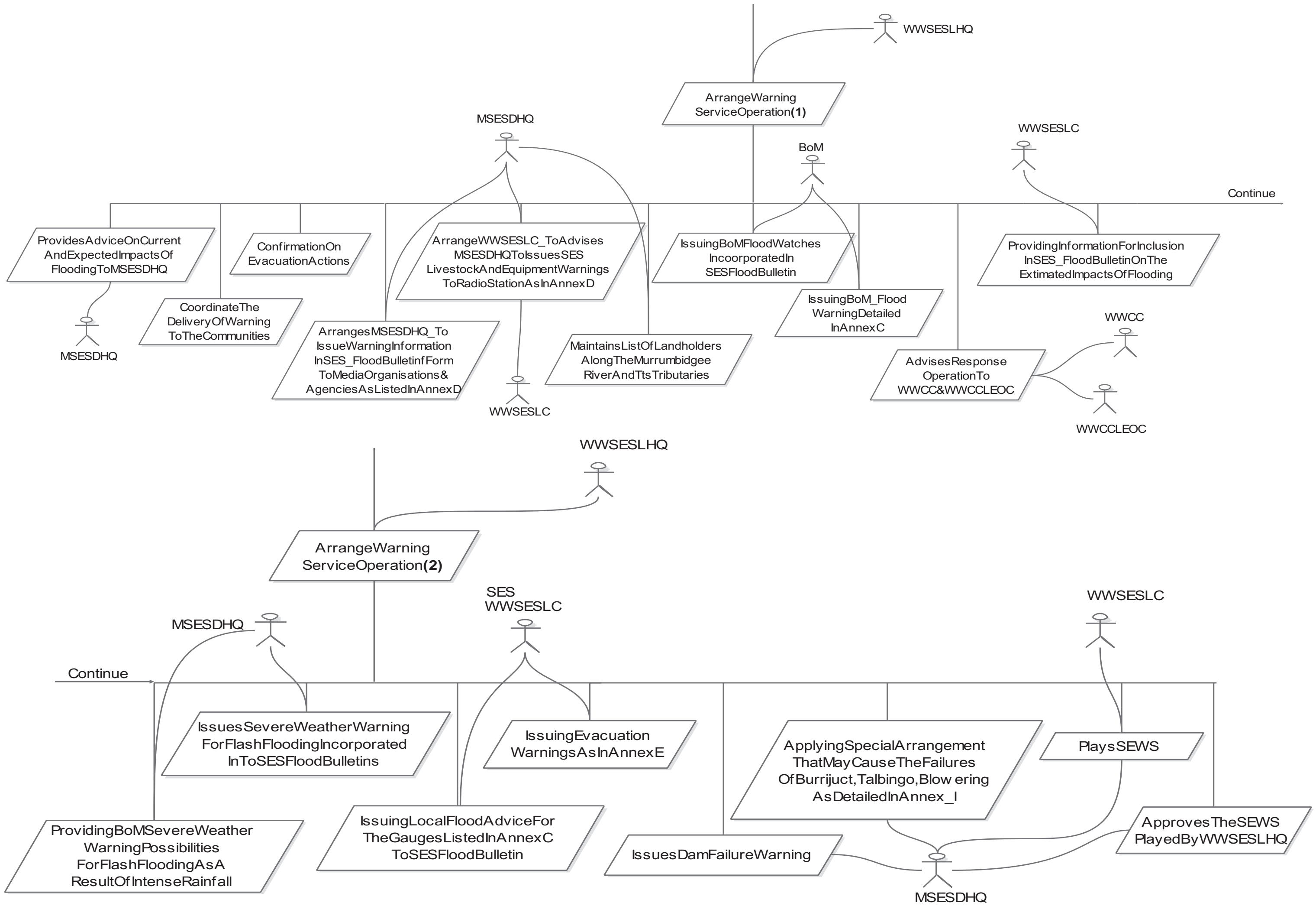
Each main goal and its sub-goals

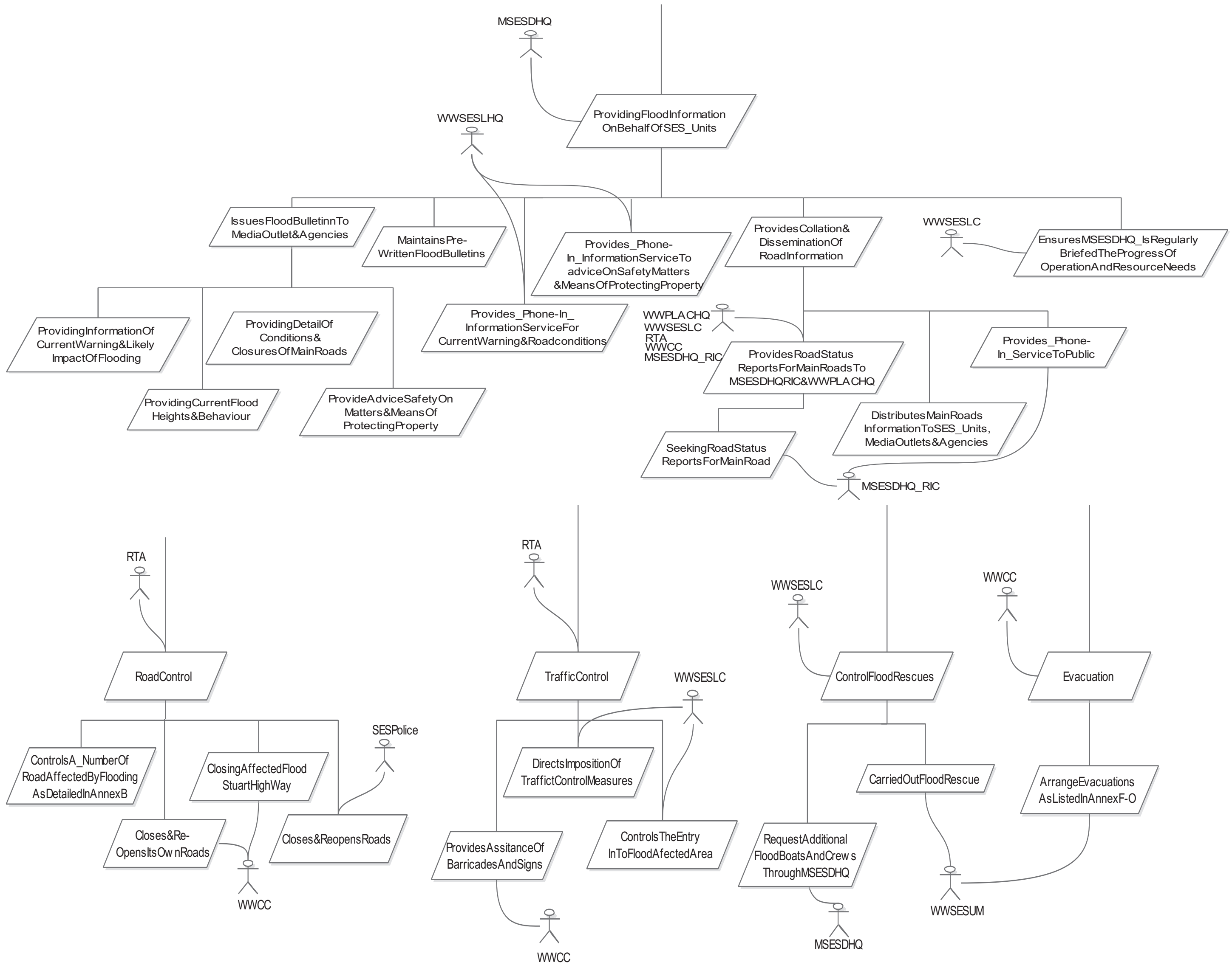

WW Local DISPLAN
ResponsePlan
SES
CFO
Coordinating FloodManagementTask
Organising FloodManagementTask
WWSESLC
MaintainOperationCentre
MaintainOCLocatedAt 208FernleighRoad
SES
OperateAnAfter HoursDutySystem
WWSESLC
RequestToProvide LO_ToWWSESOC
ProvideLO_To WWSESOC
LO_ToProvideCommunication ToParentOrganization
LO_ToAdviseOfTheir ResorceAvailability
LO_ToDeployResourcesOf ParentOrganizations
LO_RequestsToDeploy ResourcesToParentOrganizations
LOs
LOs:
WWSESLHQ
MSESDHQ
WWCC
DoIPaNR
NSWDoPI
RTA
NSWP
StateWater
SnowyHydro
WWCCLEOC
NSWPLACHQ
WWCCLEMO
DoCS
SES
WWSESLC
ProvidingCommunicationMeans
SES
ProvidingCommunicationTo OtherDeployedFieldTeams
ProvidingCommunication To&BetweenDeployedSES Resources
ProvidesBack-Up CommunicationMeans
WWSESLHQ
MSESDHQ
WWCC
DoIPaNR
NSWDoPI
RTA
NSWP
StateWater
SnowyHydro
WWCCLEOC
NSWPLACHQ
WWCCLEMO
DoCS
All Involved Organisations
WWSESLC
StartResponseOperation
WWCCLEMO
ActivatedByContacting BoM_ToDiscussFlood WarningDevelopment ThroughMSESDHQ
AdvisingCertainPersons AndOrganizationsToInitiate ResponseOperation
AdvisingOther OrganizationsAsRequested
ContactingMSESDHQ ToDiscussFlood WarningDevelopment
AssureMESEDHQ ContactingBoM_ToDiscuss FloodWarningDevelopment
MSESDHQ
BoM
InitiateResponse Operation
RequestToAdvise OtherOrganizations ToResponseOperation
WWCCM
NSWPLACHQ
WWSSLEOC

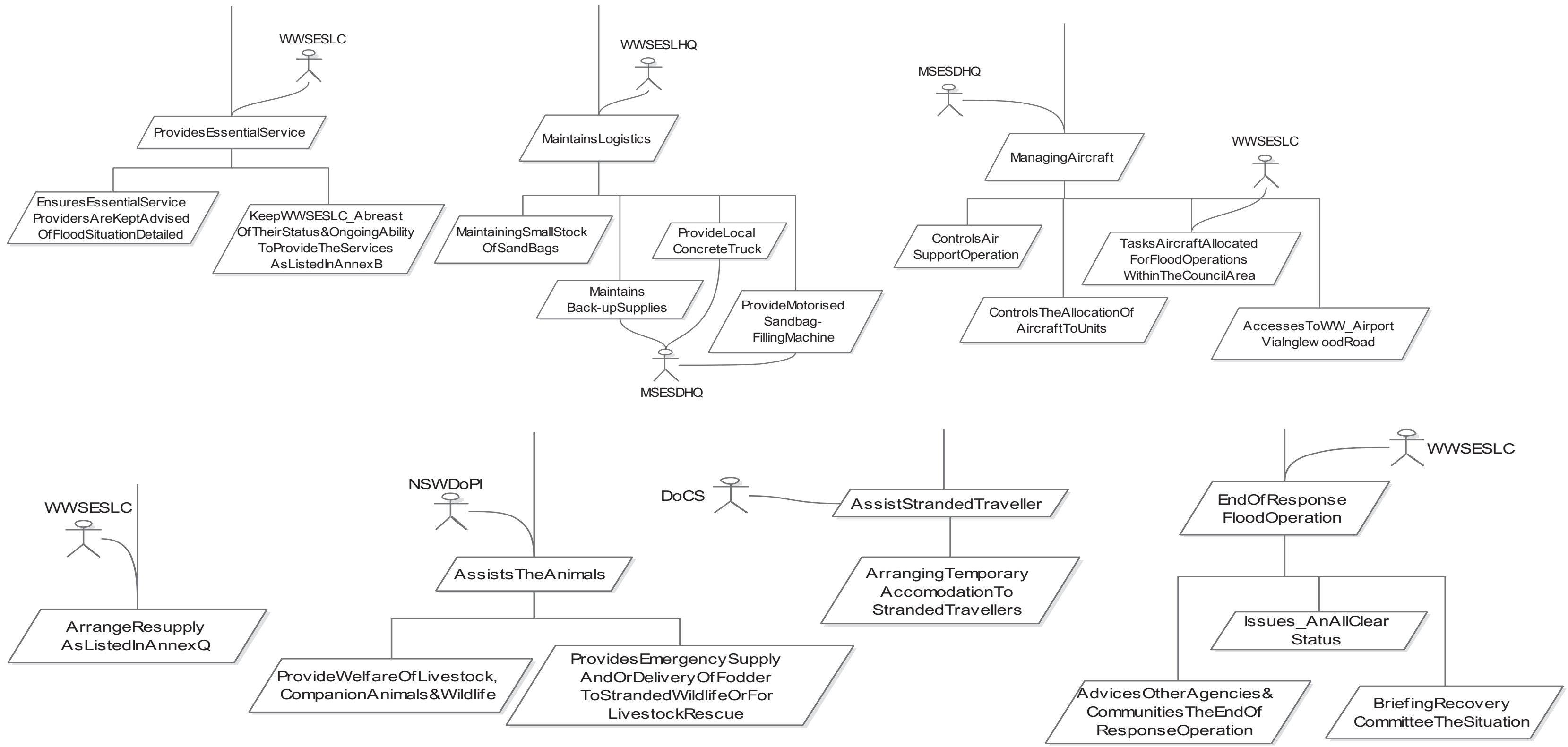

WWSESLC
MSESDHQ
Snow yHydro
StateWater
SES
ProvidingFlSources
Providing FloodWacthes
ProvideInfoAndIts ConseqOnFlooding
ProvidingInfoOn TalbingoDamFailures
ProvidingInfoOn Nurrinjuck DamFailure
Activating Reconnaissance
ProvidingInfoOn JounamaDamFailures
ProvidingSevere WeatherWarning
Providing GaugeLevel Information
AdvisingRoad Closures
AdviseFlow Rates& RatesOfRiseFor MurrumbidgeeRiver
ProvidingInfoOn Blow ering DamFailure
BoM
Providing FloodWarningToLocations AsListedInAnnexC
WWCC
DoIPaNR


WWSESLC
DeployPreliminary Resources
EnsuringResourcesAre InPlaceForDistributionOf Foodstuff&MedicalSupplies
AdviseAppropriateAgencies ToAssureOperationalCapability IsMaintained


WWSESLC
PretectionOfResources
AdvisingEmergency Services&Essential AgenciesToRelocate Resources


WWSESLHQ
ArrangeWarning ServiceOperation(1)
MSESDHQ
BoM
WWSESLC
Continue
ProvidesAdviceOnCurrent AndExpectedImpactsOf FloodingToMSESDHQ
MSESDHQ
CoordinateThe DeliveryOfWarning ToTheCommunities
ConfirmationOn EvacuationActions
ArrangesMSESDHQ_To IssueWarningInformation InSES_FloodBulletinfForm ToMediaOrganisations& AgenciesAsListedInAnnexD
ArrangeWWSESLC_ToAdvises MSESDHQToIssuesSES LivestockAndEquipmentWarnings ToRadioStationAsInAnnexD
WWSESLC
MaintainsListOfLandholders AlongTheMurrumbidgee RiverAndTtsTributaries
IssuingBoMFloodWatches IncoorporatedIn SESFloodBulletin
IssuingBoM_Flood WarningDetailed InAnnexC
ProvidingInformationForInclusion InSES_FloodBulletinOnThe ExtimatedImpactsOfFlooding
AdvisesResponse OperationTo WWCC&WWCCLEOC
WWCC
WWCCLEOC
WWSESLHQ
ArrangeWarning ServiceOperation(2)
MSESDHQ
SES WWSESLC
WWSESLC
Continue
IssuesSevereWeatherWarning ForFlashFloodingIncorporated InToSESFloodBulletins
IssuingEvacuation WarningsAsInAnnexE
ApplyingSpecialArrangement ThatMayCauseTheFailures OfBurrijuct,Talbingo,Blow ering AsDetailedInAnnex_I
PlaysSEWS
ProvidingBoMSevereWeather WarningPossibilities ForFlashFloodingAsA ResultOfIntenseRainfall
IssuingLocalFloodAdviceFor TheGaugesListedInAnnexC ToSESFloodBulletin
IssuesDamFailureWarning
ApprovesTheSEWS PlayedByWWSESLHQ
MSESDHQ


MSESDHQ
ProvidingFloodInformation OnBehalfOfSES_Units
WWSESLHQ
IssuesFloodBulletinnTo MediaOutlet&Agencies
MaintainsPre-WrittenFloodBulletins
Provides_Phone-In_InformationServiceTo adviceOnSafetyMatters &MeansOfProtectingProperty
ProvidesCollation& DisseminationOf RoadInformation
WWSESLC
EnsuresMSESDHQ_IsRegularly BriefedTheProgressOf OperationAndResourceNeeds
ProvidingInformationOf CurrentWarning&Likely ImpactOfFlooding
ProvidingDetailOf Conditions& ClosuresOfMainRoads
Provides_Phone-In_ InformationServiceFor CurrentWarning&Roadconditions
WWPLACHQ
WWSESLC
RTA
WWCC
MSESDHQ_RIC
ProvidesRoadStatus ReportsForMainRoadsTo MSESDHQRIC&WWPLACHQ
Provides_Phone-In_ServiceToPublic
ProvidingCurrentFlood Heights&Behaviour
ProvideAdviceSafetyOn Matters&MeansOf ProtectingProperty
SeekingRoadStatus ReportsForMainRoad
DistributesMainRoads InformationToSES_Units, MediaOutlets&Agencies
MSESDHQ_RIC
RTA
RoadControl
ControlsA_NumberOf RoadAffectedByFlooding AsDetailedInAnnexB
ClosingAffectedFlood StuartHighWay
SESPolice
Closes&Re-OpensItsOwnRoads
Closes&ReopensRoads
WWCC
RTA
TrafficControl
WWSESLC
DirectsImpositionOf TraffictControlMeasures
ProvidesAssitanceOf BarricadesAndSigns
ControlsTheEntry InToFloodAfectedArea
WWCC
WWSESLC
ControlFloodRescues
CarriedOutFloodRescue
RequestAdditional FloodBoatsAndCrews ThroughMSESDHQ
MSESDHQ
WWCC
Evacuation
ArrangeEvacuations AsListedInAnnexF-O
WWSESUM


WWSESLC
ProvidesEssentialService
EnsuresEssentialService ProvidersAreKeptAdvised OfFloodSituationDetailed
KeepWWSESLC_Abreast OfTheirStatus&OngoingAbility ToProvideTheServices AsListedInAnnexB
WWSESLHQ
MaintainsLogistics
MaintainingSmallStock OfSandBags
ProvideLocal ConcreteTruck
Maintains Back-upSupplies
ProvideMotorised Sandbag-FillingMachine
MSESDHQ
MSESDHQ
ManagingAircraft
WWSESLC
ControlsAir SupportOperation
TasksAircraftAllocated ForFloodOperations WithinTheCouncilArea
ControlsTheAllocationOf AircraftToUnits
AccessesToWW_Airport ViaInglew oodRoad
WWSESLC
ArrangeResupply AsListedInAnnexQ
NSWDoPI
AssistsTheAnimals
ProvideWelfareOfLivestock, CompanionAnimals&Wildlife
ProvidesEmergencySupply AndOrDeliveryOfFodder ToStrandedWildlifeOrFor LivestockRescue
DoCS
AssistStrandedTraveller
ArrangingTemporary AccomodationTo StrandedTravellers
WWSESLC
EndOfResponse FloodOperation
Issues_AnAllClear Status
AdvicesOtherAgencies& CommunitiesTheEndOf ResponseOperation
BriefingRecovery CommitteeTheSituation

2. *Role model*

DM Plan	*Role model* of the Wagga-Wagga SES NSW DISPLAN
Country	Australia
Disaster Type	Flood
Phase	Response phase

Role ID	R1
Name	**SES NSW**
Description	State Emergency Service (SES) New South Wales State
Responsibilities	1. Coordination of other agencies for flood management tasks 2. Organizing other agencies for flood management tasks 3. Operates after hours duty officer system whenever flood operations are not being conducted 4. Provides liaison (including a liaison officer (LO) where necessary) to the Wagga Wagga SES Operations Centre (WWSESEOC) 5. The LO to deploy resources of its parent organisations 6. Request a LO to deploy resources of its parent organisations 7. The LO advises the Wagga Wagga SES Local Controller on resource availability for their service 8. The LO provides communications to their own organisations 9. Provides the primary mean communications to and between deployed SES resources by mobile phone and local SES UHF radio network 10. Active Reconnaissance to provide Flood Intelligent (FI) sources by monitoring the following areas: Flowerdale flats, Main town levee, Astern section of the Sturt Hwy, Wagga Wagga Beach Caravan Park, North Wagga levee, Gumly Gumly levee, Uranquinty levee and Tarcutta levee 11. Issue Local Flood Advices for the gauges listed in Annex C to SES Flood bulletin 12. Issues Evacuation Warnings as in Annex E
Constraints	-

Role ID	R2
Name	**WWSESLHQ**
Description	Wagga – wagga SES Local Headquarter
Responsibilities	1. Provides liaison (including a LO where necessary) to the Wagga Wagga SES Operations Centre 2. The LO to deploy resources of its parent organisations 3. Request a LO to deploy resources of its parent organisations 4. The LO advises the Wagga Wagga SES Local Controller on resource availability for their service 5. The LO provides communications to their own organisations 6. Provides communications as necessary to its deployed field team 7. Provides advice to the Murrumbidgee SES Division Headquarters on current and expected impacts of flooding 8. Coordinates the delivery of warnings to the community by doorknocking, telephone, mobile public address systems, local radio stations and two-way radio 9. Confirmation of evacuation actions 10. Arranges The Murrumbidgee SES Division Headquarters to issue warning information in the form of SES Division Flood Bulletins to media organisations and agencies listed in Annex D 11. Arranges Wagga – Wagga SES Local Controller to advises the Murrumbidgee SES Division Headquarters which will issue SES Livestock and Equipment Warnings to radio stations as indicated in Annex D 12. Maintains a list of landholders along the Murrumbidgee River and its tributaries 13. Issues Bureau of Meteorology (BoM) Flood Watches that will be incorporated in SES Flood Bulletins to radio stations by the Murrumbidgee SES Division Headquarters 14. Issues Bureau of Meteorology (BoM) Flood Warnings for the locations detailed in Annex C 15. Advises response operation to the Wagga Wagga City Council (WWCC) and the Wagga Wagga City Council Local Emergency Operations Controller (WWCCLEOC) 16. Provides the Murrumbidgee SES Division Headquarters with information for inclusion in SES Flood Bulletins on the estimated impacts of flooding at the predicted heights 17. Provides Bureau of Meteorology (BoM) Severe Weather Flash flooding possibilities as a result of intense rainfall 18. Issues Bureau of Meteorology (BoM) Severe weather warnings for flash flooding that will be incorporated into SES Flood Bulletins issued by the Murrumbidgee SES Division Headquarters 19. Issue Local Flood Advices for the gauges listed in Annex C to SES Flood bulletin 20. Issues Evacuation Warnings as in Annex E 21. Issue Dam-Failure Warnings to media outlets by the Murrumbidgee SES Division Headquarters 22. Applies special arrangements in the case of severe flooding that may have the potential to cause the failure of Burrinjuck, Talbingo and Blowering Dam

	23. Plays Standard Emergency Warning Signal (SEWS) over radio and television stations to alert communities to Evacuation Warnings, Special Warnings or Dam-Failure Warnings 24. Approval to use the signal will be obtained from the Murrumbidgee SES Division Headquarters 25. Provides a 'phone-in' information service for the community in relation to current warnings, river heights, flood behaviour, road conditions and closures of local and main roads 26. Provides a 'phone-in' information service for the community in relation to advice on safety matters and means of protecting property 27. Maintains a small stock of sandbags 28. Maintains back-up supplies 29. Provides a motorised sandbag-filling machine 30. Provides local concrete trucks
Constraints	-

Role ID	R3
Name	**WWSESLC**
Description	Wagga Wagga SES Local Controller
Responsibilities	1. Maintains The Wagga Wagga City Council Emergency Operations Centre (WWCCEOC) is located at 208 Fernleigh Road 2. Operates after hours duty officer system whenever flood operations are not being conducted provide liaison (including a liaison officer where necessary) to the Wagga Wagga SES Emergency Operations Centre (WWSESEOC) 3. Request to provide liaison (including a liaison officer where necessary) to the Wagga Wagga SES Operations Centre 4. Provides liaison (including a LO where necessary) to the Wagga Wagga SES Operations Centre 5. The LO to deploy resources of its parent organisations 6. Request a LO to deploy resources of its parent organisations 7. The LO advises the Wagga Wagga SES Local Controller on resource availability for their service 8. The LO provides communications to their own organisations 9. Provides the primary mean communications to and between deployed SES resources by mobile phone and local SES UHF radio network 10. Provides communications as necessary to its deployed field team 11. Provides back-up communication means 12. Activated by contacting with the Bureau of Meteorology (BoM) to discuss the development of flood warnings which will normally be through the Murrumbidgee SES Division Headquarters 13. Contacting with the Bureau of Meteorology (BoM) to discuss the development of flood warnings 14. Assures MSESDHQ To contact Bureau of Meteorology (BoM) to discuss the development of flood warnings 15. Advising certain persons and organizations to initiate response operation for flooding anticipated response 16. Initiate response operation regardless of the location and severity of the flooding anticipated 17. Advising other agencies listed in this plan to start response operation 18. Request to advise other organizations to initiate response operation (as listed in this DM plan) as appropriate to the location and nature of the threat 19. Provides Flood Watches, which give an early appreciation of developing meteorological situations that could lead to flooding 20. Provides Flood Warnings, which include river height readings and height-time predictions as listed in Annex C 21. Provides Severe Weather Warnings for Flash Flooding 22. Provides Key gauge level information that is available from the BoM website 23. Provides information on flooding and its consequences, including those in nearby council areas 24. Advises of road closures within the council area 25. Provides information on Talbingo Dams and the likely effects of failure 26. Provides information on Jounama Dams and the likely effects of failure 27. Provides storage level information on Blowering Dam 28. Provides storage level information on Burrinjuck Dam 29. Advise flow rates and rates of rise for the Murrumbidgee River that are available on-line at http://waterinfo.dlwc.nsw.gov.au/riis/drr/index.html 30. Active Reconnaissance to provide Flood Intelligent (FI) sources by monitoring the following areas: Flowerdale flats, Main town levee, Astern section of the Sturt Hwy, Wagga Wagga Beach Caravan Park, North Wagga levee, Gumly Gumly levee, Uranquinty levee and Tarcutta levee 31. Ensure that resources are in place for the distribution of foodstuffs and medical supplies to the areas that could become isolated 32. Advise appropriate agencies so that resources (including sandbags, fire-fighting appliances, ambulances, etc.) are deployed to ensure that operational capability is maintained 33. Advise emergency services and essential agencies located on the floodplain to relocate resources to flood free locations

	34. Provides the Murrumbidgee SES Division Headquarters with information for inclusion in SES Flood Bulletins on the estimated impacts of flooding at the predicted heights 35. Issue Local Flood Advices for the gauges listed in Annex C to SES Flood bulletin 36. Issues Evacuation Warnings as in Annex E 37. Provides road status reports for main roads in the council area to the Murrumbidgee SES Division Headquarters Road Information Cell (MSESDHQRIC) and to the Wagga Wagga Police Local Area Command Headquarters (WWPLACHQ) 38. Obtains road status reports for main roads in the council area information from the Police, Council and RTA 39. Ensures that the Murrumbidgee SES Division Controller is regularly briefed on the progress of operations and on future resource needs 40. Directs the imposition of traffic control measures 41. Controls the entry into flood affected areas 42. Carries out flood rescue using high clearance vehicles, flood boats and (under some circumstances) helicopters 43. Request additional flood boats and crews through the Murrumbidgee SES Division Headquarters (MSESDHQ) 44. Provides Essential Services 45. Ensure that the providers of essential services (electricity, water, sewerage, medical and public health) are kept advised of the flood situation 46. Essential service providers must keep the Wagga Wagga SES Local Controller abreast of their status and ongoing ability as listed in Annex B 47. Task aircraft allocated by the Division Headquarters for flood operations within the council area 48. Arranges resupply as detailed in Annex Q 49. Advises other agencies and the community The end of response operation 50. Issue an 'all clear' for evacuees to return to their homes 51. Briefs the recovery committee on the situation and any need
Constraints	1. Preliminary deployments may be required for up to one week 2. In the event of major flooding, the Wagga Wagga SES Local Controller may direct the imposition of traffic control measures 3. The entry into flood affected areas will be controlled in accordance with the provisions of the State Emergency Service Act, 1989 (Part 5, Sections 19, 20, 21 and 22) and the State Emergency Rescue Management Act, 1989 (Part 4, Sections 60KA, 60L and 61) 4. Aircraft can be used for a variety of purposes during flood operations, however, should only be used if other transport means are not available or not suitable 5. The Wagga Wagga SES Local Controller may task aircraft allocated by the Division Headquarters for flood operations within the council area 6. Air support operations will be conducted under the control of the Murrumbidgee SES Division Headquarters, which may allocate aircraft to units if applicable

Role ID	R4
Name	**MSESDHQ**
Description	**Murrumbidgee State Emergency Service Division Headquarters**
Responsibilities	1. Provides liaison (including a LO where necessary) to the Wagga Wagga SES Operations Centre 2. The LO to deploy resources of its parent organisations 3. Request a LO to deploy resources of its parent organisations 4. The LO advises the Wagga Wagga SES Local Controller on resource availability for their service 5. The LO provides communications to their own organisations 6. Provides communications as necessary to its deployed field team 7. Assures MSESDHQ To contact Bureau of Meteorology (BoM) to discuss the development of flood warnings 8. Provides information on flooding and its consequences, including those in nearby council areas 9. Provides advice to the Murrumbidgee SES Division Headquarters on current and expected impacts of flooding 10. Arranges The Murrumbidgee SES Division Headquarters to issue warning information in the form of SES Division Flood Bulletins to media organisations and agencies listed in Annex D 11. Arranges Wagga – Wagga SES Local Controller to advises the Murrumbidgee SES Division Headquarters which will issue SES Livestock and Equipment Warnings to radio stations as indicated in Annex D 12. Provides Bureau of Meteorology (BoM) Severe Weather Flash flooding possibilities as a result of intense rainfall 13. Issues Bureau of Meteorology (BoM) Severe weather warnings for flash flooding that will be incorporated into SES Flood Bulletins issued by the Murrumbidgee SES Division Headquarters 14. Applies special arrangements in the case of severe flooding that may have the potential to cause the failure of Burrinjuck, Talbingo and Blowering Dam 15. Issue Dam-Failure Warnings to media outlets by the Murrumbidgee SES Division Headquarters

	16. Plays Standard Emergency Warning Signal (SEWS) over radio and television stations to alert communities to Evacuation Warnings, Special Warnings or Dam-Failure Warnings 17. Approval to use the signal will be obtained from the Murrumbidgee SES Division Headquarters 18. Provides Current warnings, together with indications of the likely impact of flooding at any predicted heights to media outlets and agencies 19. Provides Current flood heights and flood behaviour to media outlets and agencies 20. Provides Details of conditions and closures of main roads to media outlets and agencies 21. Provides Advice on safety matters and means of protecting property to media outlets and agencies 22. Maintains pre-written flood bulletins for key heights 23. Provides a 'phone-in' information service for the community in relation to current warnings, river heights, flood behaviour, road conditions and closures of local and main roads 24. Provides a 'phone-in' information service for the community in relation to advice on safety matters and means of protecting property 25. Provides collation and dissemination of road information 26. Provides road status reports for main roads in the council area to the Murrumbidgee SES Division Headquarters Road Information Cell (MSESDHQRIC) and to the Wagga Wagga Police Local Area Command Headquarters (WWPLACHQ) 27. Obtains road status reports for main roads in the council area information from the Police, Council and RTA 28. Distributes information on main roads to SES units, media outlets and agencies as part of SES Flood Bulletins 29. Provides a 'phone-in' service to the public Collation and dissemination of road information 30. Ensures that the Murrumbidgee SES Division Controller is regularly briefed on the progress of operations and on future resource needs 31. Request additional flood boats and crews through the Murrumbidgee SES Division Headquarters (MSESDHQ) 32. Maintains back-up supplies 33. Provides local concrete trucks 34. Provides a motorised sandbag-filling machine 35. Controls Air support operations 36. Controls the allocation of aircraft to units 37. Task aircraft allocated by the Division Headquarters for flood operations within the council area 38. Accesses to the Wagga Wagga Airport at Forest Hill is flood free via Inglewood Rd 39. Issues warning information in the form of SES Division Flood Bulletins to media organisations and agencies listed in Annex D 40. Issue SES Livestock and Equipment Warnings to radio stations as indicated in Annex D 41. Maintains a list of landholders along the Murrumbidgee River and its tributaries 42. Releases to radio stations Bureau of Meteorology Flood Watches that will be incorporated in SES Flood Bulletins 43. Provides a warning of the possibility for Bureau of Meteorology Severe Weather Warnings for Flash Flooding as a result of intense rainfall. This product may be issued concurrently with flood warnings and flood watches. Severe weather warnings for flash flooding will be incorporated into SES Flood Bulletins 44. Issues Dam failure warnings to media outlets issues SES Flood Bulletins to media outlets and agencies on behalf of all SES units in the Division 45. Maintains pre-written flood bulletins for key heights 46. Distributes information on main roads to SES units, media outlets and agencies as part of SES Flood Bulletins 47. Controlling the use of aircraft in a variety of purposes during flood operations including evacuation, rescue, re-supply, reconnaissance and emergency travel 48. Provide a liaison officer, where necessary, to the Wagga Wagga SES Operations Centre
Constraints	1. Aircraft can be used for a variety of purposes during flood operations, however, should only be used if other transport means are not available or not suitable 2. The Wagga Wagga SES Local Controller may task aircraft allocated by the Division Headquarters for flood operations within the council area 3. Air support operations will be conducted under the control of the Murrumbidgee SES Division Headquarters, which may allocate aircraft to units if applicable

Role ID	R5
Name	**BoM**
Description	Bureau of Meteorology of Australia
Responsibilities	1. Provides Flood Watches, which give an early appreciation of developing meteorological situations that could lead to flooding 2. Provides Flood Warnings, which include river height readings and height-time predictions as listed in Annex C 3. Provides Severe Weather Warnings for Flash Flooding

	4. Provides Key gauge level information that is available from the BoM website 5. Assures MSESDHQ To contact Bureau of Meteorology (BoM) to discuss the development of flood warnings
Constraints	-

Role ID	R6
Name	**WWCC**
Description	Wagga- Wagga City Council
Responsibilities	1. Provides liaison (including a LO where necessary) to the Wagga Wagga SES Operations Centre 2. The LO to deploy resources of its parent organisations 3. Request a LO to deploy resources of its parent organisations 4. The LO advises the Wagga Wagga SES Local Controller on resource availability for their service 5. The LO provides communications to their own organisations 6. Provides communications as necessary to its deployed field team 7. Advises of road closures within the council area 8. Advises response operation to the Wagga Wagga City Council (WWCC) and the Wagga Wagga City Council Local Emergency Operations Controller (WWCCLEOC) 9. Provides road status reports for main roads in the council area to the Murrumbidgee SES Division Headquarters Road Information Cell (MSESDHQRIC) and to the Wagga Wagga Police Local Area Command Headquarters (WWPLACHQ) 10. Obtains road status reports for main roads in the council area information from the Police, Council and RTA 11. Closes and re-opens its own roads 12. Closes the Sturt Highway within the urban centre of Wagga Wagga as effected by flooding 13. Provides assistance in the erection of barricades and signs 14. Arrangements evacuation for the Wagga Wagga City Council area as listed in Annexes F to O
Constraints	-

Role ID	R7
Name	**Snowy Hydro Ltd.**
Description	Information provider to Talbingo and Jounama Dams
Responsibilities	1. Provides liaison (including a LO where necessary) to the Wagga Wagga SES Operations Centre 2. The LO to deploy resources of its parent organisations 3. Request a LO to deploy resources of its parent organisations 4. The LO advises the Wagga Wagga SES Local Controller on resource availability for their service 5. The LO provides communications to their own organisations 6. Provides communications as necessary to its deployed field team 7. Provides information on Talbingo Dams and the likely effects of failure 8. Provides information on Jounama Dams and the likely effects of failure
Constraints	-

Role ID	R08
Name	**State Water**
Description	Information provider to Blowering and Burrinjuck Dams
Responsibilities	1. Provides liaison (including a LO where necessary) to the Wagga Wagga SES Operations Centre 2. The LO to deploy resources of its parent organisations 3. Request a LO to deploy resources of its parent organisations 4. The LO advises the Wagga Wagga SES Local Controller on resource availability for their service 5. The LO provides communications to their own organisations 6. Provides communications as necessary to its deployed field team 7. Provides storage level information on Blowering Dam 8. Provides storage level information on Burrinjuck Dam
Constraints	-

Role ID	R9
Name	**NSW DoIPaNR**
Description	New South Wales Department of Infrastructure Planning and Natural Resources, Leeton Office
Responsibilities	1. Provides liaison (including a LO where necessary) to the Wagga Wagga SES Operations Centre 2. The LO to deploy resources of its parent organisations 3. Request a LO to deploy resources of its parent organisations 4. The LO advises the Wagga Wagga SES Local Controller on resource availability for their service 5. The LO provides communications to their own organisations 6. Provides communications as necessary to its deployed field team

	7. Advise flow rates and rates of rise for the Murrumbidgee River that are available on-line at http://waterinfo.dlwc.nsw.gov.au/riis/drr/index.html
Constraints	-

Role ID	R10
Name	**NSW DoPI**
Description	New South Wales Department of Primary Industries
Responsibilities	1. Provides liaison (including a LO where necessary) to the Wagga Wagga SES Operations Centre 2. The LO to deploy resources of its parent organisations 3. Request a LO to deploy resources of its parent organisations 4. The LO advises the Wagga Wagga SES Local Controller on resource availability for their service 5. The LO provides communications to their own organisations 6. Provides communications as necessary to its deployed field team 7. Assists the animals 8. Provides welfare of livestock, companion animals and wildlife (including feeding and rescue) 9. Provides emergency supply and/or delivery of fodder to stranded livestock, or for livestock rescue
Constraints	-

Role ID	R11
Name	**RTA**
Description	Road and Traffic Authority
Responsibilities	1. Provides liaison (including a LO where necessary) to the Wagga Wagga SES Operations Centre 2. The LO to deploy resources of its parent organisations 3. Request a LO to deploy resources of its parent organisations 4. The LO advises the Wagga Wagga SES Local Controller on resource availability for their service 5. The LO provides communications to their own organisations 6. Provides communications as necessary to its deployed field team 7. Provides road status reports for main roads in the council area to the Murrumbidgee SES Division Headquarters Road Information Cell (MSESDHQRIC) and to the Wagga Wagga Police Local Area Command Headquarters (WWPLACHQ) 8. Obtains road status reports for main roads in the council area information from the Police, Council and RTA 9. Controls a number of roads within the council area are affected by flooding as detailed are provided in Annex B 10. Closes and re-opens its own roads 11. Closes the Sturt Highway within the urban centre of Wagga Wagga as effected by flooding 12. Closes and re-open roads 13. Directs the imposition of traffic control measures 14. Controls the entry into flood affected areas 15. Provides assistance in the erection of barricades and signs
Constraints	1. The NSW Police has the authority to close and re-open roads but will normally only do so (if the council or the RTA has not already acted) if public safety requires such action. 2. In the event of major flooding, the Wagga Wagga SES Local Controller may direct the imposition of traffic control measures 3. The entry into flood affected areas will be controlled in accordance with the provisions of the State Emergency Service Act, 1989 (Part 5, Sections 19, 20, 21 and 22) and the State Emergency Rescue Management Act, 1989 (Part 4, Sections 60KA, 60L and 61)

Role ID	R12
Name	**NSWP**
Description	New South Wales Police
Responsibilities	1. Provides liaison (including a LO where necessary) to the Wagga Wagga SES Operations Centre 2. The LO to deploy resources of its parent organisations 3. Request a LO to deploy resources of its parent organisations 4. The LO advises the Wagga Wagga SES Local Controller on resource availability for their service 5. The LO provides communications to their own organisations 6. Provides communications as necessary to its deployed field team 7. Closes and re-opens roads
Constraints	The NSW Police has the authority to close and re-open roads but will normally only do so (if the council or the RTA has not already acted) if public safety requires such action.

Role ID	R13

Name	**NSWPLACHQ**
Description	New South Wales Police local area Command headquarter
Responsibilities	1. Provides liaison (including a LO where necessary) to the Wagga Wagga SES Operations Centre 2. The LO to deploy resources of its parent organisations 3. Request a LO to deploy resources of its parent organisations 4. The LO advises the Wagga Wagga SES Local Controller on resource availability for their service 5. The LO provides communications to their own organisations 6. Provides communications as necessary to its deployed field team 7. Initiate response operation regardless of the location and severity of the flooding anticipated 8. Provides road status reports for main roads in the council area to the Murrumbidgee SES Division Headquarters Road Information Cell (MSESDHQRIC) and to the Wagga Wagga Police Local Area Command Headquarters (WWPLACHQ) 9. Obtains road status reports for main roads in the council area information from the Police, Council and RTA
Constraints	-

Role ID	R14
Name	**MSESDHQRIC**
Description	Murrumbidgee SES Division Headquarters Road Information Cell
Responsibilities	1. Provides liaison (including a LO where necessary) to the Wagga Wagga SES Operations Centre 2. The LO to deploy resources of its parent organisations 3. Request a LO to deploy resources of its parent organisations 4. The LO advises the Wagga Wagga SES Local Controller on resource availability for their service 5. The LO provides communications to their own organisations 6. Provides communications as necessary to its deployed field team 7. Provides road status reports for main roads in the council area to the Murrumbidgee SES Division Headquarters Road Information Cell (MSESDHQRIC) and to the Wagga Wagga Police Local Area Command Headquarters (WWPLACHQ) 8. Obtains road status reports for main roads in the council area information from the Police, Council and RTA 9. Provides a ‘phone-in’ service to the public Collation and dissemination of road information
Constraints	-

Role ID	R15
Name	**DoCS**
Description	Department of Community Service
Responsibilities	1. Provides liaison (including a LO where necessary) to the Wagga Wagga SES Operations Centre 2. The LO to deploy resources of its parent organisations 3. Request a LO to deploy resources of its parent organisations 4. The LO advises the Wagga Wagga SES Local Controller on resource availability for their service 5. The LO provides communications to their own organisations 6. Provides communications as necessary to its deployed field team 7. Assist stranded traveller 8. Arranges temporary accommodation to stranded traveller seeker
Constraints	-

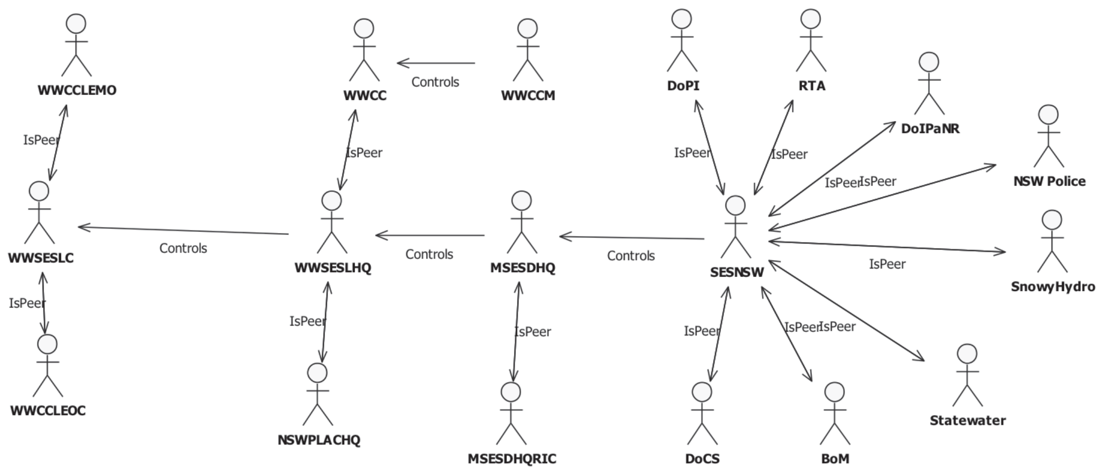
Role ID	R16
Name	**WWCCLEMO**
Description	Wagga – Wagga Citi Council Local Emergency Management Officer
Responsibilities	1. Provides liaison (including a LO where necessary) to the Wagga Wagga SES Operations Centre 2. The LO to deploy resources of its parent organisations 3. Request a LO to deploy resources of its parent organisations 4. The LO advises the Wagga Wagga SES Local Controller on resource availability for their service 5. The LO provides communications to their own organisations 6. Provides communications as necessary to its deployed field team 7. Initiate response operation regardless of the location and severity of the flooding anticipated 8. Advising other agencies listed in this plan to start response operation 9. Request to advise other organizations to initiate response operation (as listed in this DM plan) as appropriate to the location and nature of the threat
Constraints	-

Role ID	R17
Name	**WWCCLEOC**
Description	Wagga – Wagga Citi Council Local Emergency Operation Controller
Responsibilities	1. Provides liaison (including a LO where necessary) to the Wagga Wagga SES Operations Centre 2. The LO to deploy resources of its parent organisations 3. Request a LO to deploy resources of its parent organisations 4. The LO advises the Wagga Wagga SES Local Controller on resource availability for their service 5. The LO provides communications to their own organisations 6. Provides communications as necessary to its deployed field team 7. Initiate response operation regardless of the location and severity of the flooding anticipated 8. Advises response operation to the Wagga Wagga City Council (WWCC) and the Wagga Wagga City Council Local Emergency Operations Controller (WWCCLEOC)
Constraints	-

Role ID	R18
Name	**WWCCM**
Description	Wagga – Wagga Citi Council Mayor
Responsibilities	1. Initiate response operation regardless of the location and severity of the flooding anticipated
Constraints	-

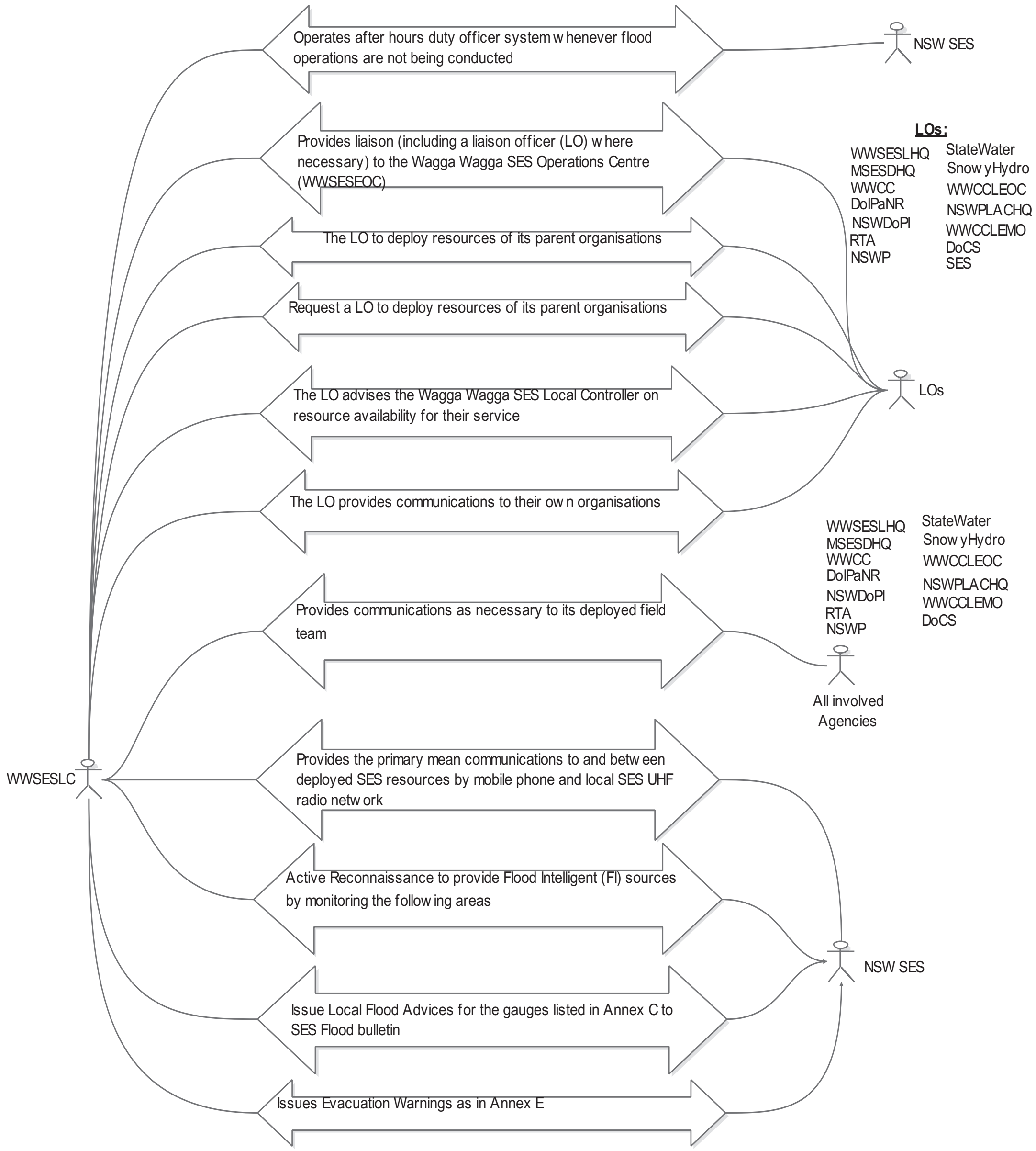
3. *Organization model*

DM Plan	Organisation model of the Wagga-Wagga SES NSW DISPLAN
Country	Australia
Disaster Type	Flood
Phase	Preparedness phase

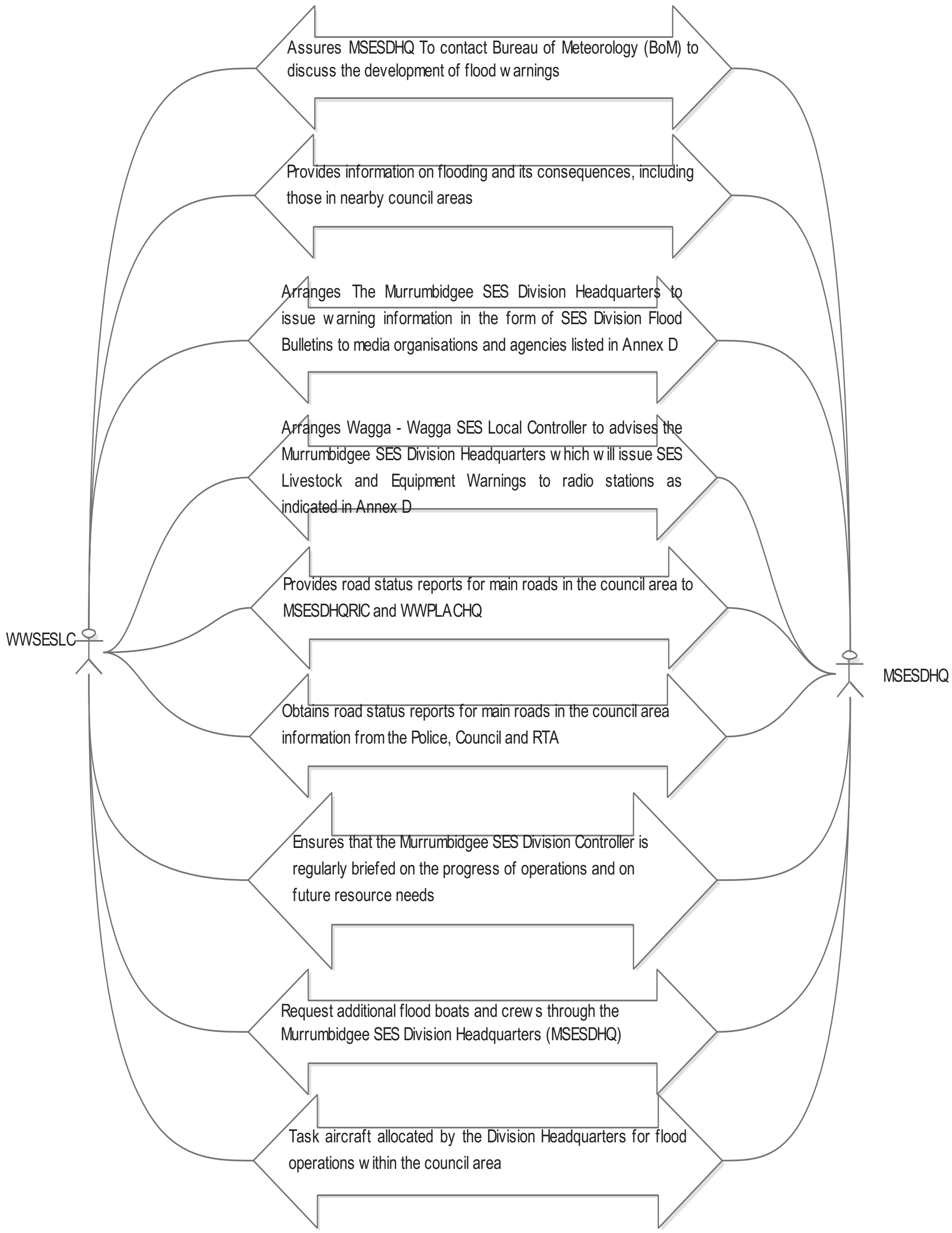


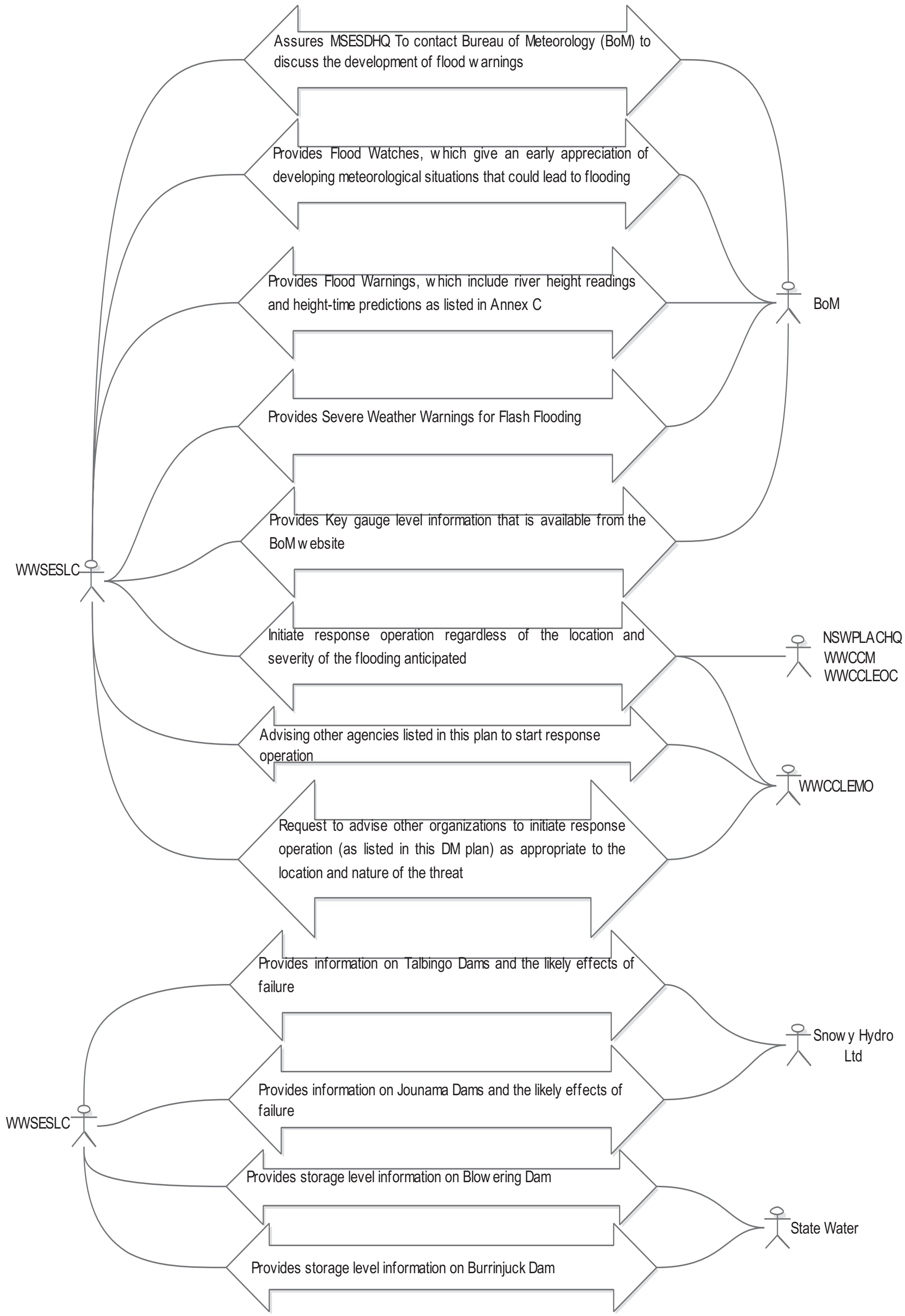
4. *Interaction model*

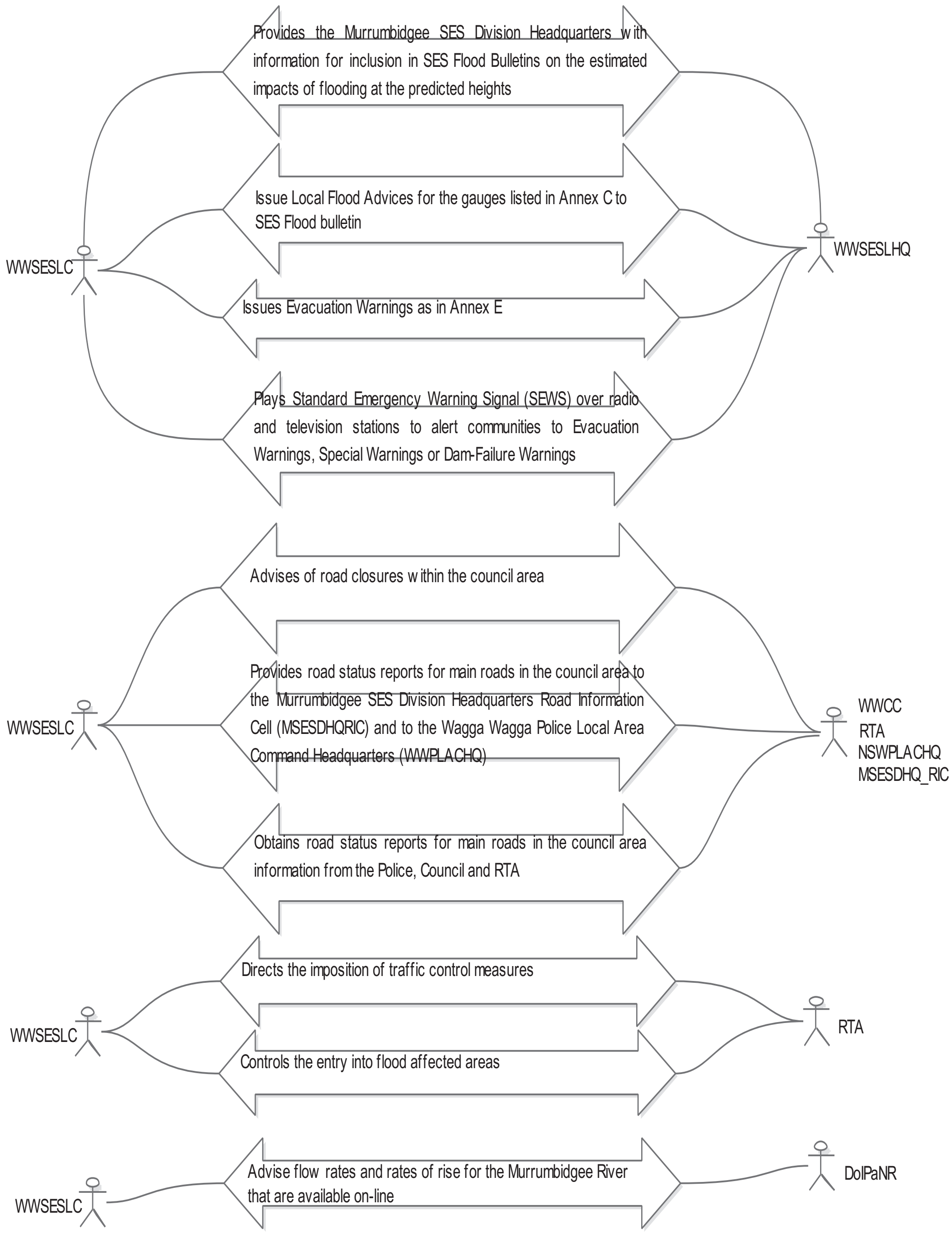
DM Plan	*Interaction model* of the Wagga-Wagga SES NSW DISPLAN
Country	Australia
Disaster Type	Flood
Phase	Response phase

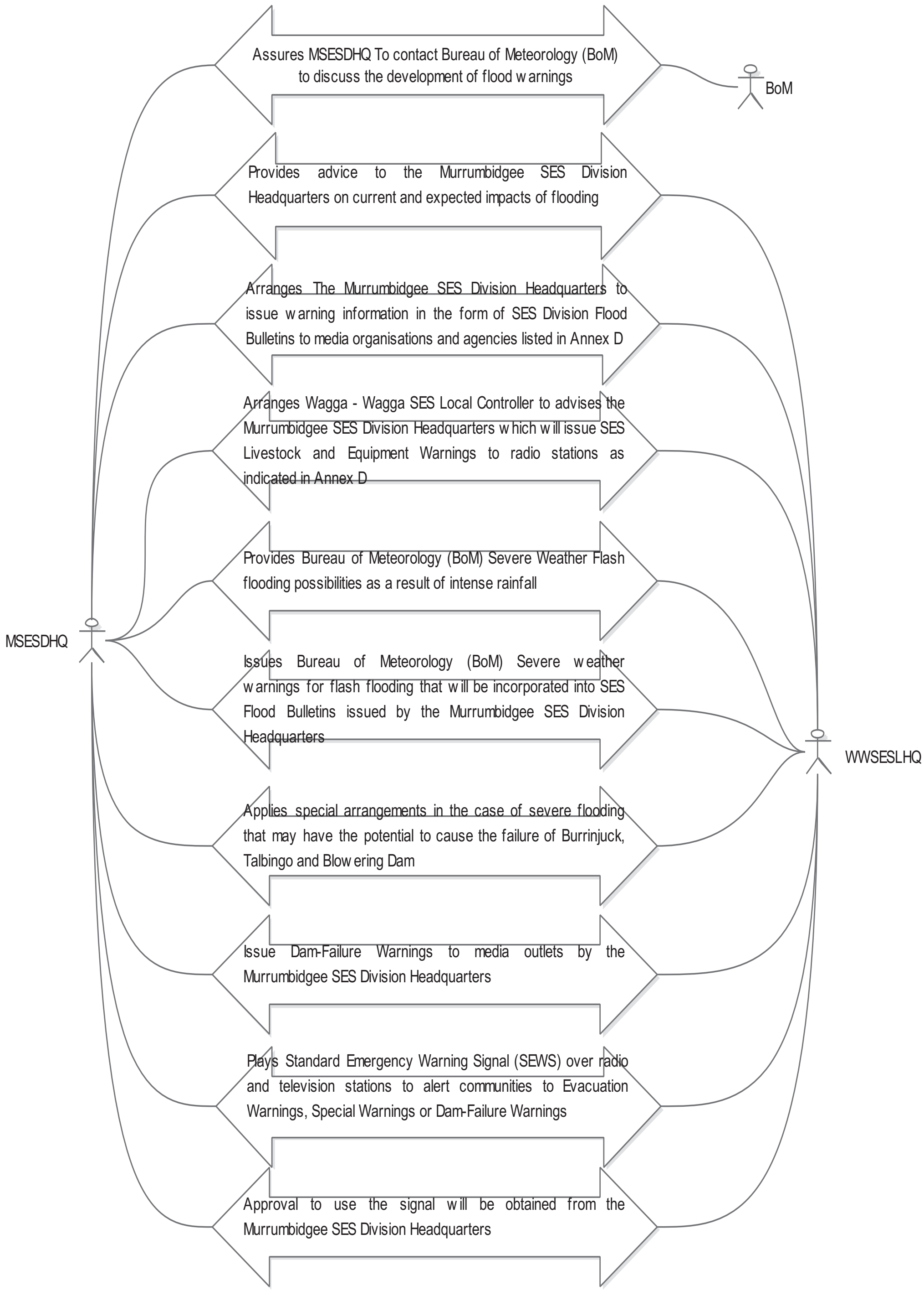


Operates after hours duty officer system w henever flood operations are not being conducted
NSW SES
Provides liaison (including a liaison officer (LO) w here necessary) to the Wagga Wagga SES Operations Centre (WWSESEOC)
LOs:
WWSESLHQ
MSESDHQ
WWCC
DoIPaNR
NSWDoPI
RTA
NSWP
StateWater
Snow yHydro
WWCCLEOC
NSWPLACHQ
WWCCLEMO
DoCS
SES
The LO to deploy resources of its parent organisations
Request a LO to deploy resources of its parent organisations
The LO advises the Wagga Wagga SES Local Controller on resource availability for their service
LOs
The LO provides communications to their ow n organisations
WWSESLHQ
MSESDHQ
WWCC
DoIPaNR
NSWDoPI
RTA
NSWP
StateWater
Snow yHydro
WWCCLEOC
NSWPLACHQ
WWCCLEMO
DoCS
Provides communications as necessary to its deployed field team
All involved Agencies
WWSESLC
Provides the primary mean communications to and betw een deployed SES resources by mobile phone and local SES UHF radio netw ork
Active Reconnaissance to provide Flood Intelligent (FI) sources by monitoring the follow ing areas
NSW SES
Issue Local Flood Advices for the gauges listed in Annex C to SES Flood bulletin
Issues Evacuation Warnings as in Annex E

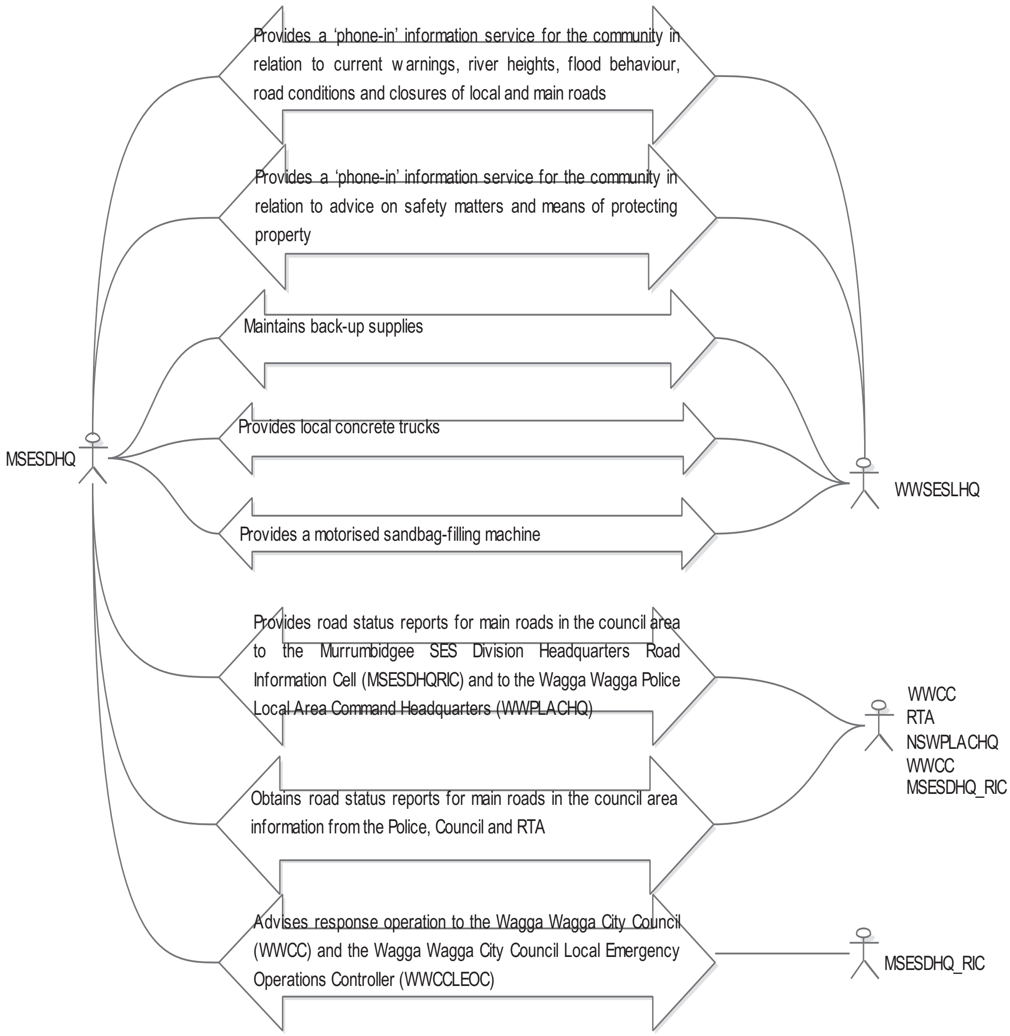

Assures MSESDHQ To contact Bureau of Meteorology (BoM) to discuss the development of flood warnings
Provides information on flooding and its consequences, including those in nearby council areas
Arranges The Murrumbidgee SES Division Headquarters to issue warning information in the form of SES Division Flood Bulletins to media organisations and agencies listed in Annex D
Arranges Wagga - Wagga SES Local Controller to advises the Murrumbidgee SES Division Headquarters which will issue SES Livestock and Equipment Warnings to radio stations as indicated in Annex D
Provides road status reports for main roads in the council area to MSESDHQRIC and WWPLACHQ
WWSESLC
MSESDHQ
Obtains road status reports for main roads in the council area information from the Police, Council and RTA
Ensures that the Murrumbidgee SES Division Controller is regularly briefed on the progress of operations and on future resource needs
Request additional flood boats and crews through the Murrumbidgee SES Division Headquarters (MSESDHQ)
Task aircraft allocated by the Division Headquarters for flood operations within the council area

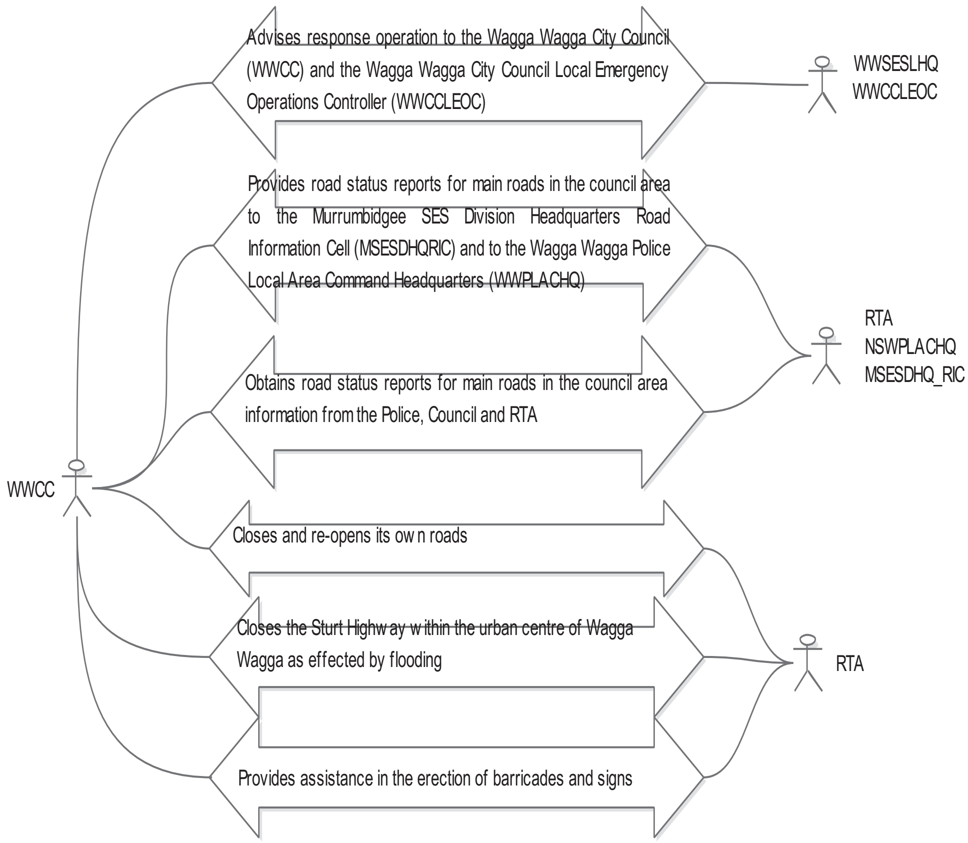

Assures MSESDHQ To contact Bureau of Meteorology (BoM) to discuss the development of flood w arnings
Provides Flood Watches, w hich give an early appreciation of developing meteorological situations that could lead to flooding
Provides Flood Warnings, w hich include river height readings and height-time predictions as listed in Annex C
BoM
Provides Severe Weather Warnings for Flash Flooding
Provides Key gauge level information that is available from the BoM w ebsite
WWSESLC
Initiate response operation regardless of the location and severity of the flooding anticipated
NSWPLACHQ
WWCCM
WWCCLEOC
Advising other agencies listed in this plan to start response operation
WWCCLEMO
Request to advise other organizations to initiate response operation (as listed in this DM plan) as appropriate to the location and nature of the threat
Provides information on Talbingo Dams and the likely effects of failure
Snow y Hydro Ltd
Provides information on Jounama Dams and the likely effects of failure
WWSESLC
Provides storage level information on Blow ering Dam
State Water
Provides storage level information on Burrinjuck Dam


Provides the Murrumbidgee SES Division Headquarters with information for inclusion in SES Flood Bulletins on the estimated impacts of flooding at the predicted heights
Issue Local Flood Advices for the gauges listed in Annex C to SES Flood bulletin
WWSESLC
WWSESLHQ
Issues Evacuation Warnings as in Annex E
Plays Standard Emergency Warning Signal (SEWS) over radio and television stations to alert communities to Evacuation Warnings, Special Warnings or Dam-Failure Warnings
Advises of road closures within the council area
Provides road status reports for main roads in the council area to the Murrumbidgee SES Division Headquarters Road Information Cell (MSESDHQRIC) and to the Wagga Wagga Police Local Area Command Headquarters (WWPLACHQ)
WWSESLC
WWCC
RTA
NSWPLACHQ
MSESDHQ_RIC
Obtains road status reports for main roads in the council area information from the Police, Council and RTA
Directs the imposition of traffic control measures
WWSESLC
RTA
Controls the entry into flood affected areas
Advise flow rates and rates of rise for the Murrumbidgee River that are available on-line
WWSESLC
DoIPaNR

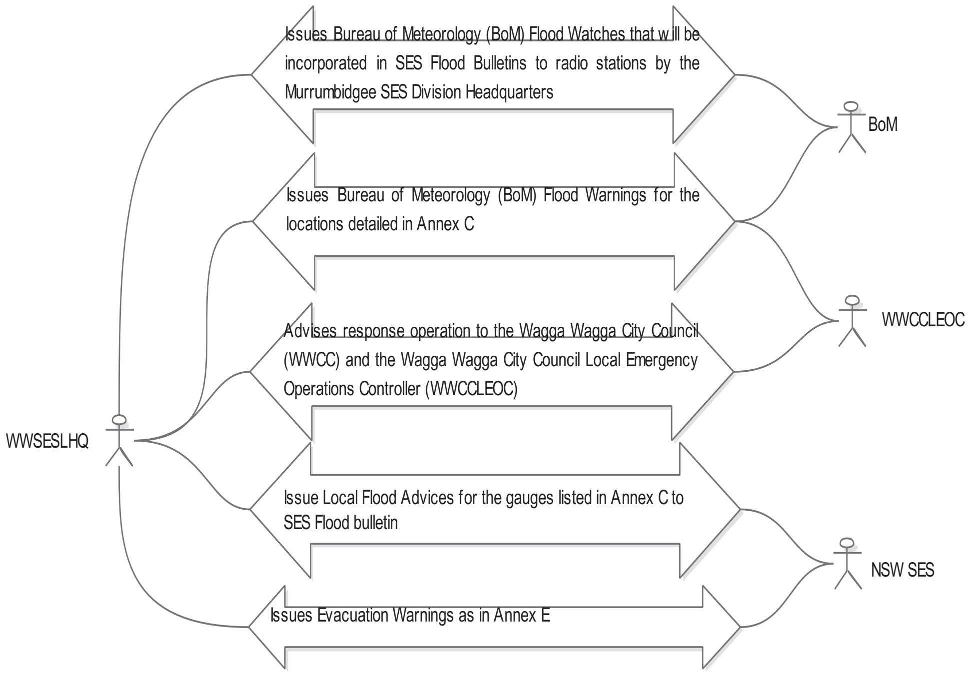


Assures MSESDHQ To contact Bureau of Meteorology (BoM) to discuss the development of flood w arnings
BoM
Provides advice to the Murrumbidgee SES Division Headquarters on current and expected impacts of flooding
Arranges The Murrumbidgee SES Division Headquarters to issue w arning information in the form of SES Division Flood Bulletins to media organisations and agencies listed in Annex D
Arranges Wagga - Wagga SES Local Controller to advises the Murrumbidgee SES Division Headquarters w hich w ill issue SES Livestock and Equipment Warnings to radio stations as indicated in Annex D
Provides Bureau of Meteorology (BoM) Severe Weather Flash flooding possibilities as a result of intense rainfall
MSESDHQ
Issues Bureau of Meteorology (BoM) Severe w eather w arnings for flash flooding that w ill be incorporated into SES Flood Bulletins issued by the Murrumbidgee SES Division Headquarters
WWSESLHQ
Applies special arrangements in the case of severe flooding that may have the potential to cause the failure of Burrinjuck, Talbingo and Blow ering Dam
Issue Dam-Failure Warnings to media outlets by the Murrumbidgee SES Division Headquarters
Plays Standard Emergency Warning Signal (SEWS) over radio and television stations to alert communities to Evacuation Warnings, Special Warnings or Dam-Failure Warnings
Approval to use the signal w ill be obtained from the Murrumbidgee SES Division Headquarters


Provides a 'phone-in' information service for the community in relation to current w arnings, river heights, flood behaviour, road conditions and closures of local and main roads
Provides a 'phone-in' information service for the community in relation to advice on safety matters and means of protecting property
Maintains back-up supplies
Provides local concrete trucks
Provides a motorised sandbag-filling machine
MSESDHQ
WWSESLHQ
Provides road status reports for main roads in the council area to the Murrumbidgee SES Division Headquarters Road Information Cell (MSESDHQRIC) and to the Wagga Wagga Police Local Area Command Headquarters (WWPLACHQ)
WWCC
RTA
NSWPLACHQ
WWCC
MSESDHQ_RIC
Obtains road status reports for main roads in the council area information from the Police, Council and RTA
Advises response operation to the Wagga Wagga City Council (WWCC) and the Wagga Wagga City Council Local Emergency Operations Controller (WWCCLEOC)
MSESDHQ_RIC


Advises response operation to the Wagga Wagga City Council (WWCC) and the Wagga Wagga City Council Local Emergency Operations Controller (WWCCLEOC)
WWSESLHQ
WWCCLEOC
Provides road status reports for main roads in the council area to the Murrumbidgee SES Division Headquarters Road Information Cell (MSESDHQRIC) and to the Wagga Wagga Police Local Area Command Headquarters (WWPLACHQ)
RTA
NSWPLACHQ
MSESDHQ_RIC
Obtains road status reports for main roads in the council area information from the Police, Council and RTA
WWCC
Closes and re-opens its own roads
Closes the Sturt Highway within the urban centre of Wagga Wagga as effected by flooding
RTA
Provides assistance in the erection of barricades and signs


RTA
Closes and re-open roads
NSW SES Police


Issues Bureau of Meteorology (BoM) Flood Watches that will be incorporated in SES Flood Bulletins to radio stations by the Murrumbidgee SES Division Headquarters
BoM
Issues Bureau of Meteorology (BoM) Flood Warnings for the locations detailed in Annex C
WWCCLEOC
Advises response operation to the Wagga Wagga City Council (WWCC) and the Wagga Wagga City Council Local Emergency Operations Controller (WWCCLEOC)
WWSESLHQ
Issue Local Flood Advices for the gauges listed in Annex C to SES Flood bulletin
NSW SES
Issues Evacuation Warnings as in Annex E

5. *Environment model*

DM Plan	*Environment model* of the Wagga-Wagga SES NSW DISPLAN
Country	Australia
Disaster Type	Flood
Phase	Response phase

E1	**List of Agencies and organizations**	
Name	Agencies and organizations	
Environment Entity ID	E1	
Description	Agencies and organisations for flood management tasks to be coordinated	
Attributes	#	Unique number distinguishing inputted data
	Type	Type agencies/organization
	Scope	Local/National
	Phone number	Phone number to be contacted
	Mobile number	Mobile number to be contacted
Roles Involved	SESLC	
	MSESDHQ	
	WWCC	
	WWUM	
	LEMO	
	WWCCM	
	WWCLEOP	
	NSWP	
	SESUM	
	LEOCON	
	NSWFB	
	RFS	
	VRA	
	DoPI	
	DoCS	
	ASoNSW	
	RailCorp	
	TSC	
	DoEaT	
	CEO	
	PSaCC	
	RARFC	
	CSU	
	SESFW	
	CPP	

E2	**List of Communications**	
Name	Communications	
Environment Entity ID	E2	
Description	Liaison officers are to be able to provide communications to their own organisations	
Attribute	#	Unique number distinguishing inputted data
	Type of communications	Radio UHF/Mobile phone, etc.
Roles Involved	SESLC	
	LOs	
	MSESDHQ	
	WWCC	
	WWUM	
	LEMO	
	WWCCM	
	WWCLEOP	
	NSWP	
	SESUM	
	LEOCON	
	NSWFB	
	RFS	
	VRA	
	DoPI	

	DoCS	
	ASoNSW	
	RailCorp	
	TSC	
	DoEaT	
	CEO	
	PSaCC	
	RARFC	
	CSU	
	SESFW	
	CPP	

E3	**List of Other agencies**	
Name	Other agencies	
Environment Entity ID	E3	
Description	Other agencies listed in this plan will be advised to start respond operation of flood	
Attribute	#	Unique number distinguishing inputted data
	List name	Nama of agencies involved in
Roles Involved	SESLC	
	LEMO	

E4	**List of The Gauges**	
Name	The Gauges	
Environment Entity ID	E4	
Description	The gauges for which predictions are provided for are listed in Annex C	
Attribute	#	Unique number distinguishing inputted data
	Gauge Names	Gauge names
Roles Involved	SESLC	
	BoM	

E5	**List of Resources for distribution**	
Name	Resources for distribution	
Environment Entity ID	E5	
Description	Wagga Wagga SES Local Controller will ensure that resources are in place for the distribution of foodstuffs and medical supplies to the areas that could become isolated	
Attribute	#	Unique number distinguishing inputted data
	Type of resources	Type of resources
	Availability	Yes/No
Roles Involved	SESLC	

E6	**List of Appropriate agencies**	
Name	**Appropriate agencies**	
Environment Entity ID	E6	
Description	Appropriate agencies will be advised When towns and villages are expected to become isolated to deploy resources (including sandbags, firefighting appliances, ambulances, etc.). Pre-deployments may be required for up to one week	
Attribute	#	Unique number distinguishing inputted data
	Type	Type agencies/organization
	Scope	Local/National
Roles Involved	SESLC	

E7	**List of Resources to be deployed**	
Name	Resources to be deployed	
Environment Entity ID	E7	
Description	Resources (including sandbags, firefighting appliances, ambulances, etc.), when towns and villages are expected to become isolated, are deployed to ensure that operational capability is maintained. Pre-deployments may be required for up to one week	
Attribute	#	Unique number distinguishing inputted data
	Type of resources	Type of resources
	Availability	Yes/No
Roles Involved	SESLC	

E8	**List of Emergency services**

Name	Resources to be deployed	
Environment Entity ID	E8	
Description	Resources (including sandbags, firefighting appliances, ambulances, etc.), when towns and villages are expected to become isolated, are deployed to ensure that operational capability is maintained. Pre-deployments may be required for up to one week	
Attribute	#	Unique number distinguishing inputted data
	Type of services	Type of service
	Communication type	Mean to communicated with
	Contact number	Contact number
Roles Involved	SESLC	

E9	**List of Essential agencies**	
Name	Resources to be deployed	
Environment Entity ID	E9	
Description	Resources (including sandbags, firefighting appliances, ambulances, etc.), when towns and villages are expected to become isolated, are deployed to ensure that operational capability is maintained. Pre-deployments may be required for up to one week	
Attribute	#	Unique number distinguishing inputted data
	Type	Type agencies/organization
	Scope	Local/National
	Contact number	Contact number
Roles Involved	SESLC	

E10	**List of Media organizations and agencies**	
Name	**Media organizations agencies**	
Environment Entity ID	E10	
Description	Media organisations and agencies listed in Annex D	
Attribute	#	Unique number distinguishing inputted data
	Type	TV/Radio etc.
	Scope	Local/National
	Contact number	Contact number
Roles Involved	SESLC	
	MSESDHQ	

E11	**List of Landholders**	
Name	List of landholders	
Environment Entity ID	E11	
Description	List of landholders along the Murrumbidgee River and its tributaries	
Attribute	#	Unique number distinguishing inputted the data
	Name	Name of the landholder
	Address	Address
	Contact number	Contact numbers to reach them
Roles Involved	SESLC	
	MSESDHQ	
	WWSESLHQ	

E12	**Flood watch**	
Name	Flood watch	
Environment Entity ID	E12	
Description	Flood Watches will be incorporated in SES Flood Bulletins released to radio stations If there are signs of impending floods	
Attribute	#	Unique number distinguishing inputted data
	Forecast to flood	Prediction analysis of flood disaster
Roles Involved	SESLC	
	MSESDHQ	

E13	**Flash flood**	
Name	Flash flood	
Environment Entity ID	E13	
Description	Provides a warning of the possibility for flash flooding as a result of intense rainfall. These warnings are issued when severe weather is expected to affect land based communities with 6 to 24 hours.	
Attribute	#	Unique number distinguishing inputted data

	Time prediction	TV/Radio etc.
	Impact to communities	Prediction of area of impacted communities
	Effects	Effect that will happen
Roles Involved	SESLC	
	MSESDHQ	

E14	**Warning massage template for evacuation**	
Name	Template Warning massage template for evacuation	
Environment Entity ID	E14	
Description	A template guide to the content of evacuation warning messages is at Annex E	
Attribute	#	Unique number distinguishing inputted data
	Warning for	TV/Radio etc.
	Authorized by	Local/National
Roles Involved	SESLC	
	MSESDHQ	

E15	**Detail arrangement for evacuation**	
Name	Detail arrangement for evacuation	
Environment Entity ID	E15	
Description	Special arrangements apply in the case of severe flooding that may have the potential to cause the failure of Burrinjuck, Talbingo and Blowering Dam. Details of these arrangements are described in Annex I	
Attribute	#	Unique number distinguishing inputted data
	Authorized by	Local/National
Roles Involved	SESLC	
	MSESDHQ	

E16	**Dams Failure warning**	
Name	Dams Failure warning	
Environment Entity ID	E16	
Description	Details of these arrangements are described in Annex I. Dam failure warnings will be issued to media outlets by the Murrumbidgee SES Division Headquarters	
Attribute	#	Unique number distinguishing inputted data
	Authorized by	Local/National
Roles Involved	SESLC	
	MSESDHQ	

E17	**Information of SES flood bulletin**	
Name	SES flood bulletin	
Environment Entity ID	E17	
Description	The Murrumbidgee SES Division Headquarters issues SES Flood Bulletins to media outlets and agencies on behalf of all SES units in the Division. SES Flood Bulletins contain the following information relating to all council areas in which flooding is occurring	
Attribute	#	Unique number distinguishing inputted data
	Type of warning	Local/National
	Flood heights and flood behavior	flood heights and flood behavior
	Flood and road condition	Details of conditions and closures of main roads
	Advice	Advice on safety matters and means of protecting property
Roles Involved	SESLC	
	MSESDHQ	

E18	**Infrastructure list of possible risk**	
Name	Infrastructure list of possible risk	
Environment Entity ID	E18	
Description	Infrastructure at risk of flood damage as listed in Annex B	
Attribute	#	Unique number distinguishing inputted data
	Infrastructure name	Infrastructure name
Roles Involved	SESLC	
	MSESDHQ	

6. *Agent model*

DM Plan	*Agent model* of the Wagga-Wagga SES NSW DISPLAN
Country	Australia
Disaster Type	Flood
Phase	Response phase

Agent Type	SESNSW Type
Name	**SESNSW**
Description	Play role as the SES New State Wales
References	**R01**
Activity	**Activity Name :** Control Operation **Functionality :** Control Operation **Trigger :** Control of response operation **Action :** 1. Coordination of other agencies for flood management tasks 2. Organizing other agencies for flood management tasks
	Activity Name : Operate operation centre **Functionality :** Operate operation centre **Trigger :** Organizing response operation **Action :** Operates after hours duty officer system whenever flood operations are not being conducted
	Activity Name : Provide Flood Intelligence (FI) **Functionality :** Provide Flood Intelligence (FI) **Trigger :** Flood Intelligence (FI) gathering to response operation **Action :** Monitoring source of Flood Intelligence (FI) for the following areas: Flowerdale flats, Main town levee, Astern section of the Sturt Hwy, Wagga Wagga Beach Caravan Park, North Wagga levee, Gumly Gumly levee, Uranquinty levee and Tarcutta levee
	Activity Name : Issuing warning **Functionality :** Issuing warning **Trigger :** Operate warning services **Action :** Issuing Local Flood Advices for the gauges listed in Annex C. These are issued in SES Division Flood Bulletins and/or direct from the Wagga Wagga SES Local Controller via facsimile
	Activity Name : Provide Liaison Officer (LO) **Functionality :** Provide Liaison Officer (LO) **Trigger :** At the request of SESLC **Action :** Provide a liaison officer, where necessary, to the Wagga Wagga SES Operations Centre
Environment Considerations	[E1] **Agencies and organizations**

Agent Type	SESLC Type
Name	**SESLC**
Description	Play role as the SES Local Controller
References	**R02**
Activity	**Activity Name :** Operate operation centre **Functionality :** Operate operation centre **Trigger :** 1. Operate operation center for response plan **Action :** Maintains an Operations Centre at 208 Fernleigh Road, Wagga Wagga
	Activity Name : Request to provide LO **Functionality :** Request to provide LO **Trigger :** Control response operation **Action :** Request to provide liaison (including a liaison officer where necessary) to the Wagga Wagga SES Operations Centre
	Activity Name : Start of response operation **Functionality :** Start of response operation **Trigger :** 1. On receipt of a Bureau of Meteorology Preliminary Flood Warning, Flood Warning, Flood Watch or Severe Weather Warning for Flash Flooding 2. On receipt of dam-failure warnings for Burrinjuck, Blowering or Talbingo Dams 3. When other evidence leads to an expectation of flooding within the council area

Action :	1. Contact with the Bureau of Meteorology (BoM) to discuss the development of flood warnings which will normally be through the MSESDHQ 2. Advising WWCCLEOC for flooding anticipated response (for transmission to the NSW Police Local Area Command Headquarters 3. Advising WWSESU to initiate response operation for flooding anticipated response 4. Advising MSESDHQ to initiate response operation for flooding anticipated response 5. Advising WWCCLEMO to initiate response operation for flooding anticipated response 6. Advising WWCCM to initiate response operation for flooding anticipated response 7. Request to advise other organizations to initiate response operation (as listed in this DM plan) for flooding anticipated response 8. Request to initiate response operation for flood anticipated based on appropriate of the location to other organizations as listed in this DM plan
Activity Name :	Preliminary deployments
Functionality :	Preliminary deployments
Trigger :	Preliminary deployments to start response operation
Action :	1. Ensuring that resources are in place for the distribution of foodstuffs and medical supplies to the areas that could become isolated 2. Advising appropriate agencies so that resources (including sandbags, firefighting appliances, ambulances, etc.) are deployed to ensure that operational capability is maintained. Pre-deployments may be required for up to one week
Activity Name :	Protection of resources
Functionality :	Protection of resources
Trigger :	Protection of resources of the response operation
Action :	Advising emergency services and essential agencies located on the floodplain to relocate resources to flood free locations
Activity Name :	SES livestock and equipment warning
Functionality :	SES livestock and equipment warning
Trigger :	Following heavy rain or when there are indications of significant creek or river rises (even to levels below Minor Flood heights)
Action :	Advising the MSESDHQ to issue SES Livestock and Equipment Warnings to radio stations as indicated in Annex D
Activity Name :	BoM Flood Warning
Functionality :	BoM Flood Warning
Trigger :	On receipt BoM Flood Warnings for the locations detailed in Annex C
Action :	1. Advise the Wagga Wagga City Council (WWCC) and the Wagga Wagga City Council Local Emergency Operations Controller (WWCCLEOC) of flood warning 2. Provide the Murrumbidgee SES Division Headquarters (MSESDHQ) with information for inclusion in SES Flood Bulletins on the estimated impacts of flooding at the predicted heights
Activity Name :	Evacuation warning
Functionality :	Evacuation warning
Trigger :	When evacuation is required
Action :	Issuing evacuation warning messages as a template is at Annex E
Activity Name :	Playing SEWS
Functionality :	Playing SEWS
Trigger :	When there are Evacuation Warnings or Special Warnings or Dam-Failure Warnings
Action :	Standard Emergency Warning Signal (SEWS) may be played over radio and television stations to alert communities to Evacuation Warnings, Special Warnings or Dam-Failure Warnings
Activity Name :	Collation and dissemination read information
Functionality :	Collation and dissemination read information
Trigger :	When response operation
Action :	1. Provides road status reports for main roads in the council area to the Murrumbidgee SES Division Headquarters Road Information Cell

	(MSESDHQRIC) and to the Wagga Wagga Police Local Area Command Headquarters (WWPLACHQ) 2. Ensuring that the Murrumbidgee SES Division Controller is regularly briefed on the progress of operations and on future resource needs
Activity Name : **Functionality :** **Trigger :** **Action :**	Traffic control Traffic control In the event of major flooding Direct the imposition of traffic control measures
Activity Name : **Functionality :** **Trigger :** **Action :**	Flood rescue Flood rescue When response operation 1. Controls flood rescues, which are carried out using high clearance vehicles, flood boats and (under some circumstances) helicopters 2. Request additional flood boats and crews through the Murrumbidgee SES Division Headquarters
Activity Name : **Functionality :** **Trigger :** **Action :**	Keep inform essential service Keep inform essential service When response operation 1. Ensuring that the providers of essential services (electricity, water, sewerage, medical and public health) are kept advised of the flood situation 2. Kept to be informed status and ongoing ability from Essential service providers
Activity Name : **Functionality :** **Trigger :** **Action :**	Maintain logistic Maintain logistic When response operation Maintaining a small stock of sandbags and back-up supplies are available through the Murrumbidgee SES Division Headquarters. A motorised sandbag-filling machine is available from Murrumbidgee Division Headquarters. Alternatively, local concrete trucks may be used
Activity Name : **Functionality :** **Trigger :** **Action :**	Managing aircraft Managing aircraft Should only be used if other transport means are not available or not suitable Task the aircraft allocated by the Division Headquarters for flood operations within the council area
Activity Name : **Functionality :** **Trigger :** **Action :**	Resupply Resupply When response operation Arranging resupply as the details listed in Annex Q
Activity Name : **Functionality :** **Trigger :** **Action :**	Assistance of animals Assistance of animals When response operation 1. Refers to the matters relating to the welfare of livestock, companion animals and wildlife (including feeding and rescue) to NSW Department of Primary Industries 2. Requests for emergency supply and/or delivery of fodder to stranded livestock, or for livestock rescue, are to be passed to NSW Department of Primary Industries
Activity Name : **Functionality :** **Trigger :** **Action :**	Assist stranded travellers Assist stranded travellers When response operation Refers the stranded travellers to Department of Community Services for the arrangement of temporary accommodation
Activity Name : **Functionality :** **Trigger :** **Action :**	End of response operation End of response operation When response operation 1. Advising agencies and the community involved in response operation the end of response operation 2. Briefing Recovery Committee (RC) on the situation and any need to issue an ‘all clear’ for evacuees to return to their homes

Environment Considerations	[E5]	**Resources for distribution**
	[E6]	**Appropriate agencies**
	[E7]	**Resources to be deployed**
	[E8]	**Emergency services**
	[E9]	**Essential agencies**
	[E14]	**Warning massage template for evacuation**
	[E18]	**Infrastructure list of possible risk**
	[E19]	**Resupply arrangements**

Agent Type	LO Type
Name	**LO**
Description	Play role as the Liaison Officer
References	**R03**
Activity	**Activity Name :** Deploy the resource **Functionality :** Deploy the resource **Trigger :** At the request of the WWSESLC **Action :** 1. Deploy the resources of their parent organisations 2. Advise the Wagga Wagga SES Local Controller on resource availability for their service 3. Provide communications to their own organisations
Environment Considerations	[E2] **Communications**

7. *Scenario model*

DM Plan	*Scenario model* of the Wagga-Wagga SES NSW DISPLAN
Country	Australia
Disaster Type	Flood
Phase	Response phase

Scenario	S01
Name	**Control Flood Operation**
Goal	**CFO**
Initiator	SES (SESNSW)
Trigger	For starting the control of flood operation
Pre-condition	-
Post-condition	-
Description	-

Condition	Step	Activity	Role	Environment Entity
		Coordination of other agencies and organizations for flood management tasks	SES(NSW)	E1

Scenario	S02
Name	**Maintain Operation Centre**
Goal	Maintain Operation Centre
Initiator	SESLC
Trigger	For starting the control of flood operation
Pre-condition	-
Post-condition	-
Description	-

Condition	Step	Activity	Role	Environment Entity
Sequential	1	Maintains an Operations Centre at 208 Fernleigh Road, Wagga Wagga	SES(NSW), SESLC	
	2	Operates after hours duty officer system whenever flood operations are not being conducted	SES	

	3	Request to provide liaison (including a liaison officer where necessary) to the Wagga Wagga SES Operations Centre	SESLC	
	4	Provide a liaison officer, where necessary, to the Wagga Wagga SES Operations Centre	SESLC,LO	E1
	5	LO to deploy the resources of their parent organisations at the request of the Wagga Wagga SES Local Controller	LO, SESLC	
	6	LO to advise the Wagga Wagga SES Local Controller on resource availability for their service	LO, SESLC	
	7	LO to provide communications to their own organisations	LO, SESLC	E2

Scenario	S03
Name	**Start of Response Operation**
Goal	Start of Response Operation
Initiator	SESLC
Trigger	4. On receipt of a Bureau of Meteorology Preliminary Flood Warning, Flood Warning, Flood Watch or Severe Weather Warning for Flash Flooding 5. On receipt of dam-failure warnings for Burrinjuck, Blowering or Talbingo Dams 6. When other evidence leads to an expectation of flooding within the council area
Pre-condition	-
Post-condition	-
Description	-

Condition	**Step**	**Activity**	**Role**	**Environment Entity**
Sequential	1	Contact with the Bureau of Meteorology to discuss the development of flood warnings will normally be through the MSESDHQ	SES(NSW), SESLC	
	2	Advising WWCCLEOC for flooding anticipated response (for transmission to the NSW Police Local Area Command Headquarters	SES	
	3	Request to advise other organizations to initiate response operation (as listed in this DM plan) for flooding anticipation	SESLC, WWCCLEMO	E1
	4	Advises other agencies listed in this plan to start the response operation regardless of the location and severity of the flooding to the appropriate location and the nature of the threat.	SESLC, WWCCLEMO	E1,E3

Scenario	S04
Name	**Providing Flood Intelligence (FI) Sources**
Goal	Providing Flood Intelligence (FI) Sources
Initiator	BoM
Trigger	Times of flooding
Pre-condition	-
Post-condition	-
Description	-

Condition	**Step**	**Activity**	**Role**	**Environment Entity**
Sequential	1	Provides Flood Watches, which give an early appreciation of developing meteorological situations that could lead to flooding. These are normally provided on a whole-catchment basis for the Murrumbidgee River catchment	BoM, MSESDHQ, SESLC	
	2	Provides Flood Warnings, which include river height readings and height-time predictions. The gauges for which predictions are provided for are listed in Annex C	BoM, MSESDHQ, SESLC	E4

Condition	Step	Activity	Role	Environment Entity
	3	Provides Severe Weather Warnings for Flash Flooding	BoM, MSESDHQ, SESLC	
	4	Provides Key gauge level information is available from the BoM website, www.bom.gov.au	BoM, MSESDHQ, SESLC	
	5	provides information on flooding and its consequences, including those in nearby council areas	MSESDHQ, SESLC	
	6	Advise of road closures within the council area	WWCC	
	7	Provides information on Talbingo and Jounama Dams and the likely effects of failure	Snowy Hydro, MSESDHQ, SESLC	
	8	Provides storage level information on Blowering Dam	State Water, MSESDHQ, SESLC	
	9	Provides storage level information on Burrinjuck Dam	State Water, MSESDHQ, SESLC	
	10	Advises flow rates and rates of rise for the Murrumbidgee River. Daily river level report are available on-line at http://waterinfo.dlwc.nsw.gov.au/riis/drr/index.html	DoIPaNS, MSESDHQ, SESLC	
	11	Active reconnaissance	SES (NSW), SESLC	E4

Scenario	S05
Name	**Preliminary Deployment**
Goal	Preliminary Deployment
Initiator	SESLC
Trigger	1. When flooding is expected to be severe enough to cut road access to towns, within towns and/or rural communities 2. When towns and villages are expected to become isolated
Pre-condition	-
Post-condition	-
Description	-

Condition	Step	Activity	Role	Environment Entity
Interleave	1	Ensuring that resources are in place for the distribution of foodstuffs and medical supplies to the areas that could become isolated	SES(NSW), SESLC	E5
	2	Advising appropriate agencies so that resources (including sandbags, firefighting appliances, ambulances, etc.) are deployed to ensure that operational capability is maintained. Pre-deployments may be required for up to one week	SES	E6

Scenario	S06
Name	**Protection of Resources**
Goal	Protection of Resources
Initiator	SESLC
Trigger	When the Wagga - Wagga levee is predicted to overtop or fail
Pre-condition	-
Post-condition	-
Description	-

Condition	Step	Activity	Role	Environment Entity
		Advising emergency services and essential agencies located on the floodplain to relocate resources to flood free locations	SES(NSW), SESLC	E8,E9

Scenario		S07		
Name		**Arrange Warning Service Operations**		
Goal		Arrange Warning Service Operations		
Initiator		SESLHQ		
Trigger		-		
Pre-condition				
Post-condition		-		
Description		-		
Condition	**Step**	**Activity**	**Role**	**Environment Entity**
Sequential	1	Advices to the Murrumbidgee SES Division Headquarters on current and expected impacts of flooding	SESLHQ, MSESDHQ	
	2	Coordinates the delivery of warnings to the community by doorknocking, telephone, mobile public address systems, local radio stations and two-way radio	SESLHQ	
	3	Confirmation of evacuation actions	SESLHQ	
	4	The MSESDHQ issues warning information in the form of SES Division Flood Bulletins to media organisations and agencies listed in Annex D.	SESLC, MSESDHQ	E10
	5	Advises the MSESDHQ which will issue SES Livestock and Equipment Warnings to radio stations as indicated in Annex D	SESLC, MSESDHQ	E10
	6	Issues SES Livestock and Equipment Warnings to radio stations as indicated in Annex D	MSESDHQ, ESLC	E10
	7	Maintains a list of landholders along the Murrumbidgee River and its tributaries	MSESDHQ, SSLC	E11

Scenario		S08		
Name		**Release BoM Flood Watches**		
Goal		Release BoM Flood Watches		
Initiator		MSESDHQ		
Trigger		If there are signs of impending floods		
Pre-condition				
Post-condition		-		
Description		-		
Condition	**Step**	**Activity**	**Role**	**Environment Entity**
Sequential	1	Releases BoM Flood Watches to radio stations which will be incorporated in SES Flood Bulletins	MSESDHQ, SESLC	E12
	2	Issues BoM Flood Warnings as detailed in Annex C	MSESDHQ	
	3	Advise the WWCC and the WWCCLEOC Controller of impending flooding	SESLC, WWCC, WWCCLEOC	
	4	Provide the MSESDHQ with information for inclusion in SES Flood Bulletins on the estimated impacts of flooding at the predicted heights		E17

Scenario		S09		
Name		**Provides BoM Severe Weather Warnings for Flash Flooding**		
Goal		Provides BoM Severe Weather Warnings for Flash Flooding		
Initiator		MSESDHQ		
Trigger		An intense rainfall		
Pre-condition		when severe weather is expected to affect land based communities with 6 to 24 Hours		
Post-condition		-		
Description		-		
Condition	**Step**	**Activity**	**Role**	**Environment Entity**

Sequential	1	Provides a warning of the possibility for Bureau of Meteorology Severe Weather Warnings for Flash Flooding as a result of intense rainfall. This product may be issued concurrently with flood warnings and flood watches. Severe weather warnings for flash flooding will be incorporated into SES Flood Bulletins	MSESDHQ, SESLC	E13
	2	Issues Local Flood Advices for the gauges listed in Annex C. These are issued in SES Division Flood Bulletins and/or direct from the Wagga Wagga SES Local Controller via facsimile.	MSESDHQ, SESLC	E17

Scenario		S10		
Name		**Issues Evacuation Warning**		
Goal		Issues Evacuation Warning		
Initiator		SESLC		
Trigger		When evacuation is required		
Pre-condition		in the case of severe flooding that may have the potential to cause the failure of Burrinjuck, Talbingo and Blowering Dam		
Post-condition		-		
Description		-		
Condition	**Step**	**Activity**	**Role**	**Environment Entity**
Interleave	1	Issues Evacuation Warning	MSESDHQ, SESLC	E14
	2	Issues Dam failure warnings to media outlets by the MSESDHQ. Details of these arrangements are described in Annex I	MSESDHQ, SESLC	E15
	3	Standard Emergency Warning Signal (SEWS) may be played over radio and television stations to alert communities to Evacuation Warnings, Special Warnings or Dam-Failure Warnings	SESLC, SESLHQ, MSESDHQ	

Scenario		S11		
Name		**Issues Flood Information on behalf SES units**		
Goal		Issues Flood Information on behalf SES units		
Initiator		SESLC		
Trigger		When evacuation is required		
Pre-condition		in the case of severe flooding that may have the potential to cause the failure of Burrinjuck, Talbingo and Blowering Dam		
Post-condition		-		
Description		-		
Condition	**Step**	**Activity**	**Role**	**Environment Entity**
Sequential	1	Maintains pre-written flood bulletins for key heights	MSESDHQ	E10,E17
	2	Provides a 'phone-in' information service for the community in relation to current warnings, river heights, flood behaviour, road conditions and closures of local and main roads	MSESDHQ	
	3	Provides advice on safety matters and means of protecting property	MSESDHQ	E10
	4	Provides road status reports for main roads in the council area to the MSESDHQRIC and to the WWPLACHQ	MSESDHQ, MSESDHQ, WWPLACHQ	
	5	Distributes information on main roads to SES units, media outlets and agencies as part of SES Flood Bulletins		E10
	6	RIC (MSESDHQRIC) also provides a 'phone-in' service to the public		
	7	Ensures that the MSESDHQ is regularly briefed on the progress of operations and on future resource needs		

Scenario	S12			
Name	**Road Control**			
Goal	Road Control			
Initiator	SESLC			
Trigger	When evacuation is required			
Pre-condition	in the case of severe flooding that may have the potential to cause the failure of Burrinjuck, Talbingo and Blowering Dam			
Post-condition	-			
Description	-			
Condition	**Step**	**Activity**	**Role**	**Environment Entity**
Interleave	1	Closes and re-opens its own roads	WWCC	E14
	2	close and re-open roads but will normally only do so (if the council or the RTA have not already acted) if public safety requires such action	NSWP, RTA	

Scenario	S13			
Name	**Traffic Control**			
Goal	Traffic Control			
Initiator	SESLC			
Trigger	In the event of major flooding			
Pre-condition	in the case of severe flooding that may have the potential to cause the failure of Burrinjuck, Talbingo and Blowering Dam			
Post-condition	-			
Description	-			
Condition	**Step**	**Activity**	**Role**	**Environment Entity**
Sequential	1	Direct the imposition of traffic control measures	SESLC	
	2	Provided assistance to WWSESLC in the erection of barricades and signs	WWCC, SESLC	
	3	Controls flood rescues, which are carried out using high clearance vehicles, flood boats and (under some circumstances) helicopters	SESLC	
	4	Request additional flood boats and crews through the Murrumbidgee SES Division Headquarters	WWCC, SESLC	
	5	Arranging evacuation for the Wagga Wagga City Council area as listed in Annexes F to O		
	6	Ensures that the providers of essential services (electricity, water, sewerage, medical and public health) are kept advised of the flood situation. The detail of essential services as listed in Annex B		
	7	Essential service providers must keep the Wagga Wagga SES Local Controller abreast of their status and ongoing ability to provide those services.	SESLC	E18
	8	Maintains a small stock of sandbags, and back-up supplies are available through the Murrumbidgee SES Division Headquarters. A motorised sandbag-filling machine is available from Murrumbidgee Division Headquarters. Alternatively, local concrete trucks may be used.	SESLHQ, MSESDHQ	

Scenario	S14
Name	**Managing aircraft**
Goal	Managing aircraft
Initiator	SESLC
Trigger	Should only be used if other transport means are not available or not suitable
Pre-condition	
Post-condition	-
Description	-

Condition	Step	Activity	Role	Environment Entity
Sequential	1	Control air support operations	MSESDHQ, SESLC	
	2	Tasks aircraft allocated by the Division Headquarters for flood operations within the council area	MSESDHQ, SESLC	

Scenario	S15
Name	**Resupply operation**
Goal	Resupply operation
Initiator	SESLC
Trigger	During periods of flooding many rural properties and some villages can become isolated
Pre-condition	-
Post-condition	-
Description	-

Condition	Step	Activity	Role	Environment Entity
Sequential		Resupply arrangements are detailed in Annex Q	SESLC	

Scenario	S16
Name	**Assistance for Animal**
Goal	Assistance for Animal
Initiator	SESLC
Trigger	During periods of flooding many rural properties and some villages can become isolated
Pre-condition	-
Post-condition	-
Description	-

Condition	Step	Activity	Role	Environment Entity
Sequential	1	Refers matters relating to the welfare of livestock, companion animals and wildlife (including feeding and rescue) to NSW DoPI	SESLC, DoPI	
	2	Requests for emergency supply and/or delivery of fodder to stranded livestock, or for livestock rescue, are to be passed to NSW DoPI	SESLC, DoPI	

Scenario	S17
Name	**Stranded Travellers**
Goal	Stranded Travellers
Initiator	SESLC
Trigger	Flood waters can strand travellers
Pre-condition	-
Post-condition	-
Description	-

Condition	Step	Activity	Role	Environment Entity
		Refers to DoPI for travellers who seeking assistance for temporary accommodation	SESLC, DoPI	

Scenario	S18
Name	**End of Response Operation**
Goal	End of Response Operation
Initiator	SESLC
Trigger	When response operations have concluded
Pre-condition	-
Post-condition	-
Description	-

Condition	Step	Activity	Role	Environment Entity
Sequential	1	Advises other agencies and the community of the end of response operation	SESLC, DoPI	
	2	The recovery committee if established will be briefed on the situation and any need to issue an 'all clear' for evacuees to return to their homes.	SESLC, RC	

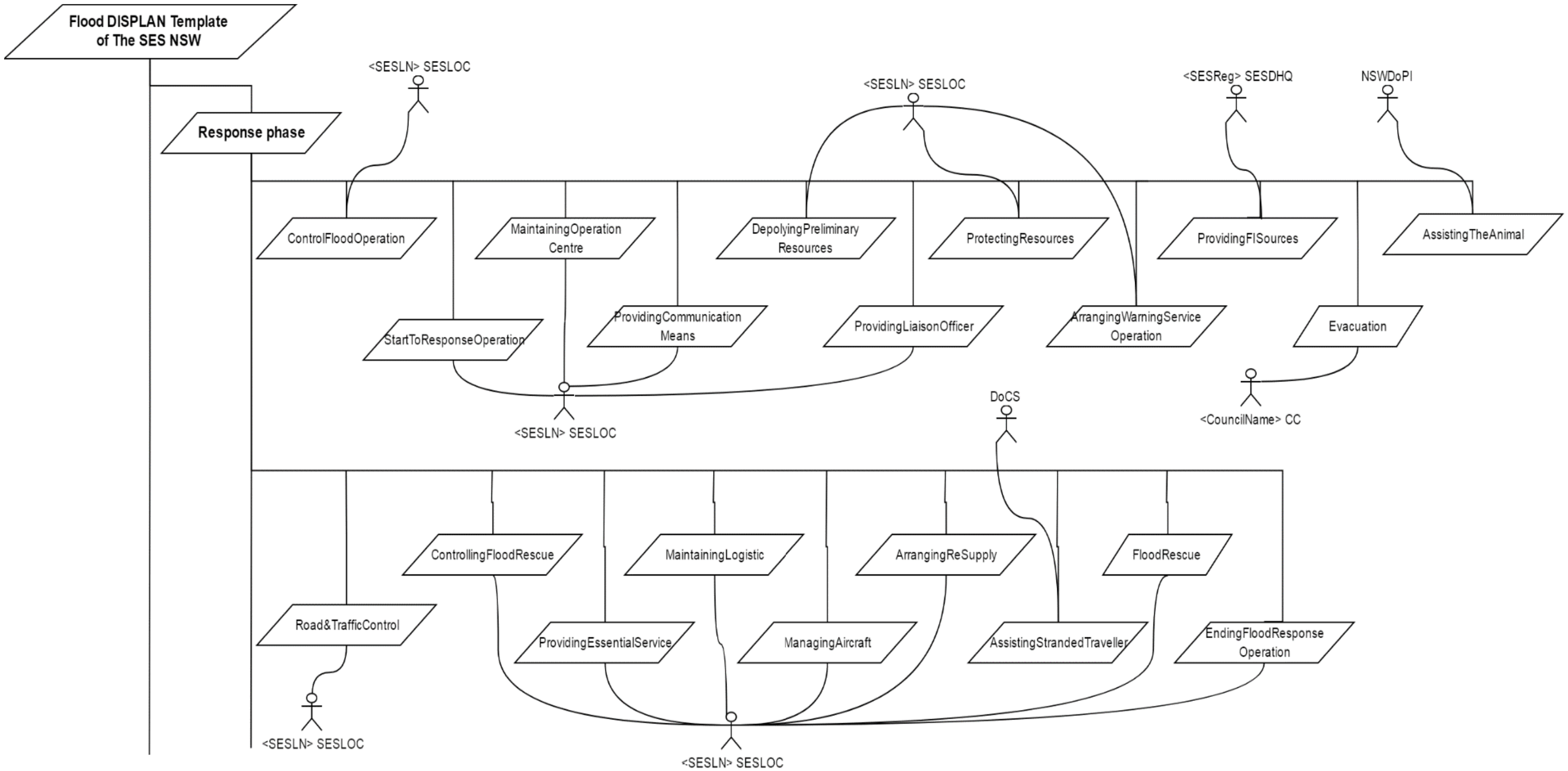
Appendix D

Customised ABMs of the SES NSW DISPLAN template

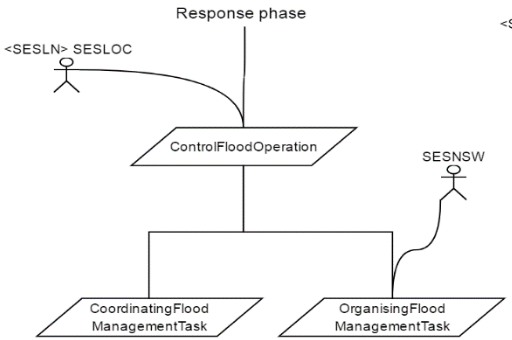
DM Plan	*Customised goal model* of the SES NSW DISPLAN template
Country	Australia
Disaster Type	Flood
Phase	Response Phase

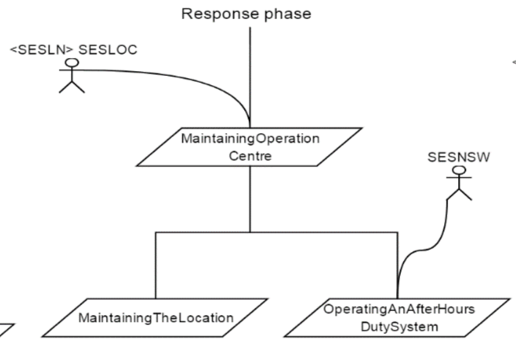
1. *Customised goal model of the SES NSW DISPLAN template*

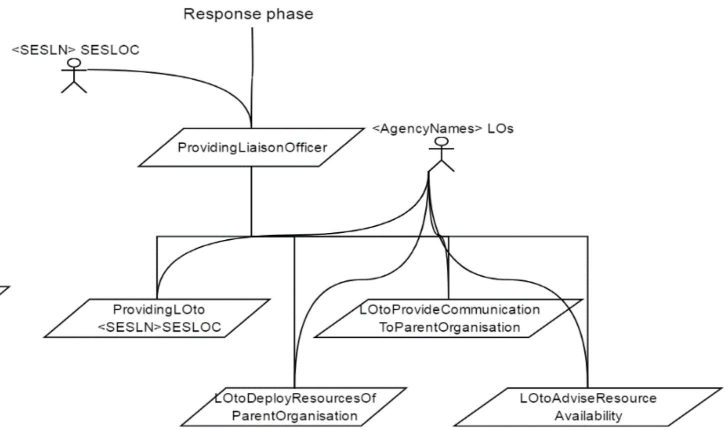
Main goals

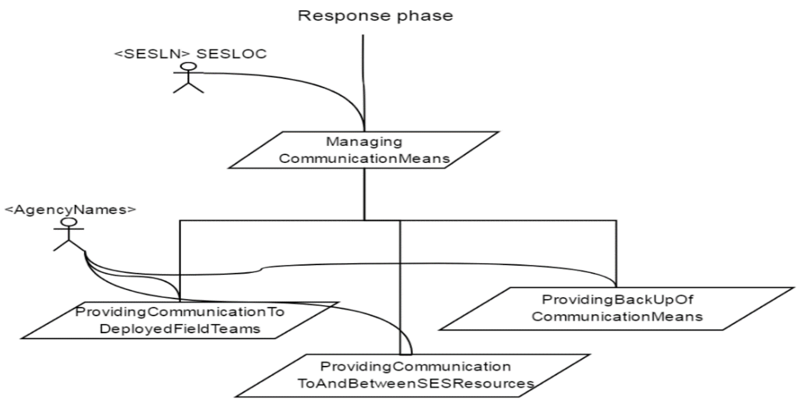


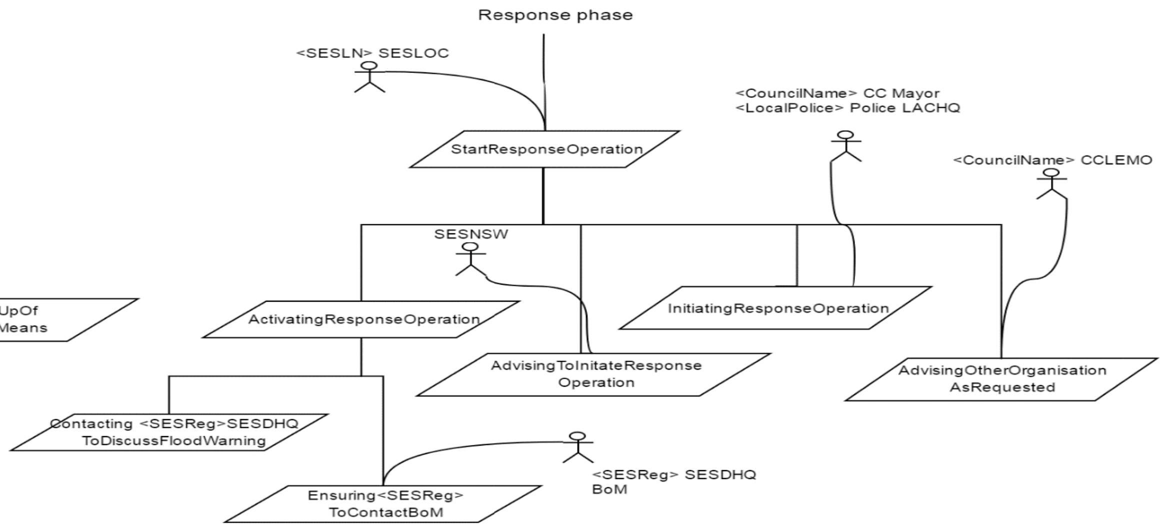
Each main goal and its sub-goals

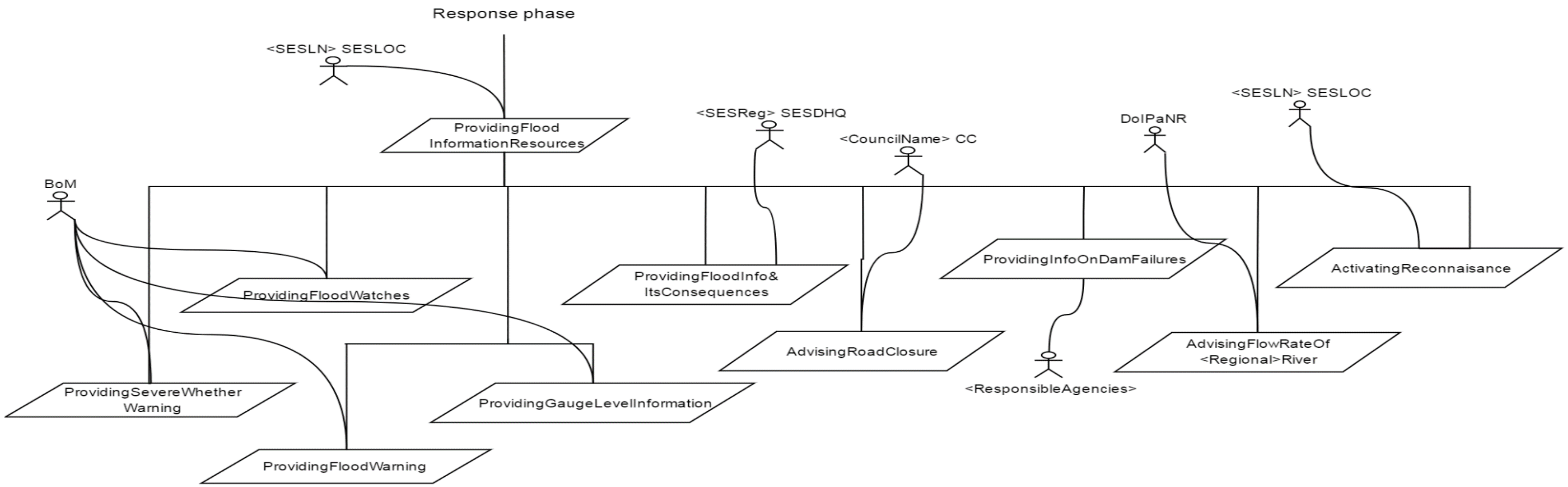











Response phase
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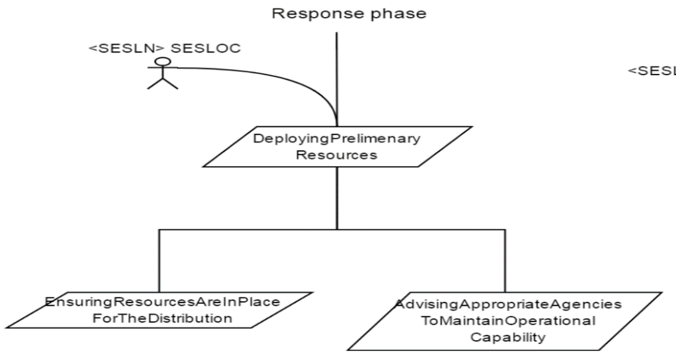
ProvidingFlood InformationResources
<SESReg> SESDHQ
<CouncilName> CC
DoIPaNR
<SESLN> SESLOC
BoM
ProvidingFloodWatches
ProvidingFloodInfo& ItsConsequences
ProvidingInfoOnDamFailures
ActivatingReconnaisance
AdvisingRoadClosure
AdvisingFlowRateOf <Regional>River
<ResponsibleAgencies>
ProvidingSevereWhether Warning
ProvidingGaugeLevelInformation
ProvidingFloodWarning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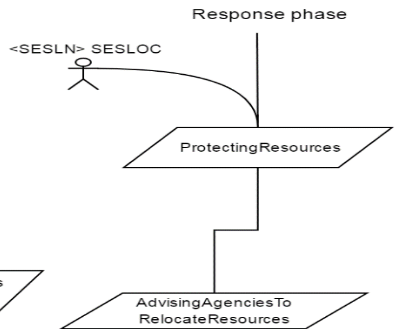
DeployingPrelimenary Resources
EnsuringResourcesAreInPlace ForTheDistribution
AdvisingAppropriateAgencies ToMaintainOperational Capability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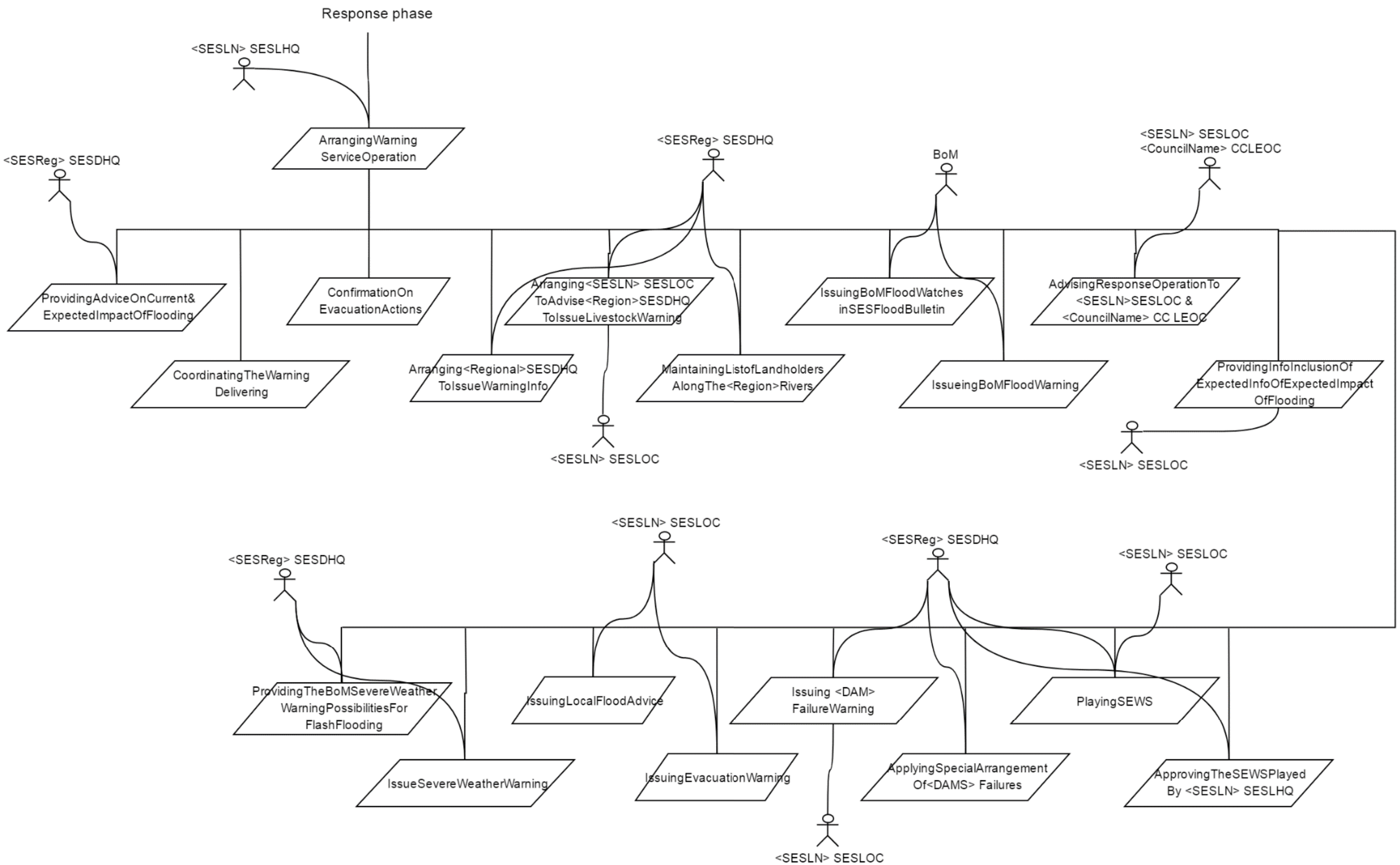
ProtectingResources
AdvisingAgenciesTo RelocateResources


Response phase
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ArrangingWarning ServiceOperation
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BoM
<SESLN> SESLOC
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ProvidingAdviceOnCurrent& ExpectedImpactOfFlooding
ConfirmationOn EvacuationActions
Arranging<SESLN> SESLOC ToAdvise<Region>SESDHQ ToIssueLivestockWarning
IssuingBoMFloodWatches inSESFloodBulletin
AdvisingResponseOperationTo <SESLN>SESLOC & <CouncilName> CC LEOC
CoordinatingTheWarning Delivering
Arranging<Regional>SESDHQ ToIssueWarningInfo
MaintainingListofLandholders AlongThe<Region>Rivers
IssueingBoMFloodWarning
ProvidingInfoInclusionOf ExpectedInfoOfExpectedImpact OfFlooding
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<SESLN> SESLOC
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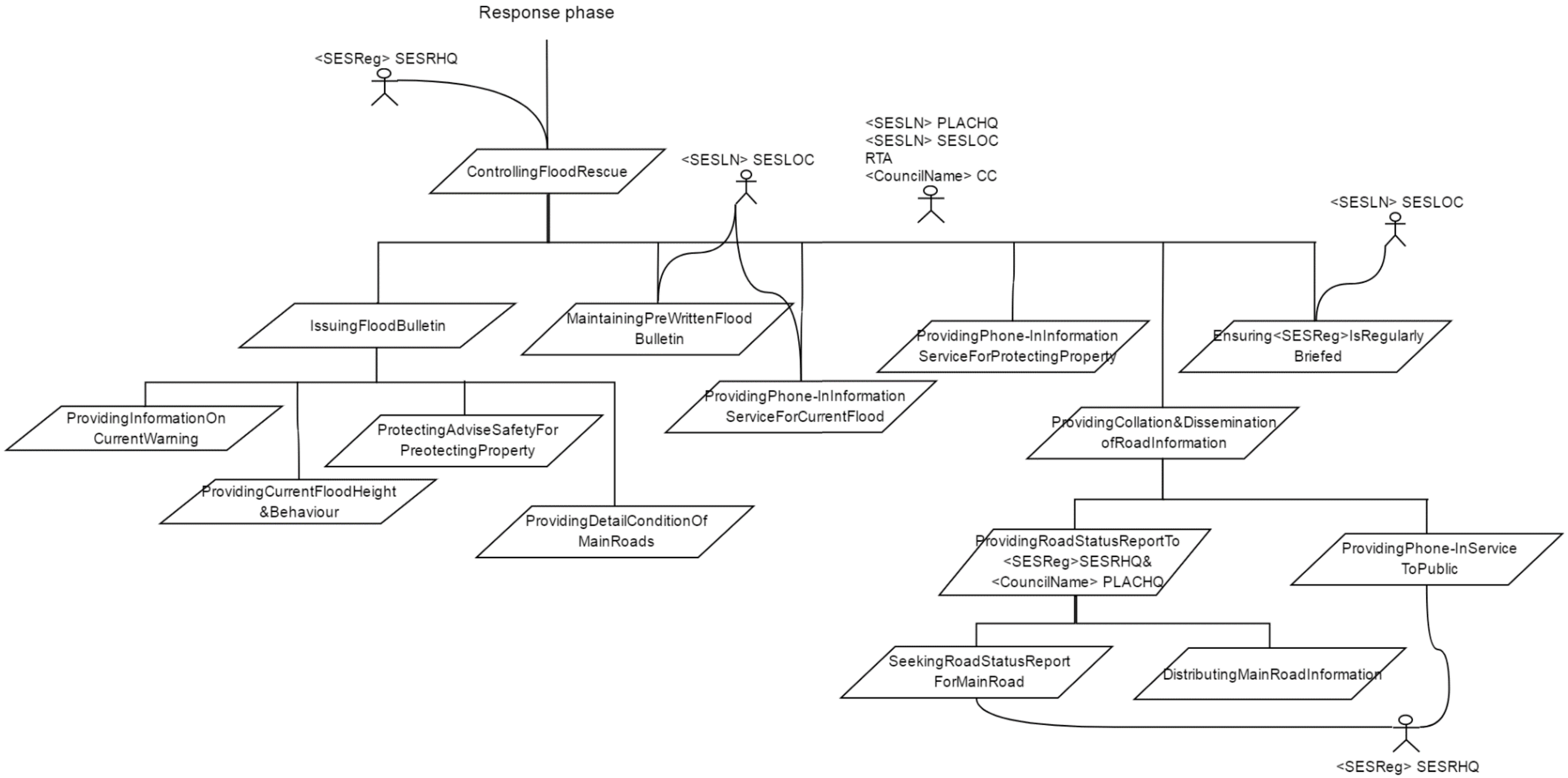
<SESReg> SESDHQ
<SESReg> SESDHQ
<SESLN> SESLOC
ProvidingTheBoMSevereWeather WarningPossibilitiesFor FlashFlooding
IssuingLocalFloodAdvice
Issuing <DAM> FailureWarning
PlayingSEWS
IssueSevereWeatherWarning
IssuingEvacuationWarning
ApplyingSpecialArrangement Of<DAMS> Failures
ApprovingTheSEWSPlayed By <SESLN> SESLHQ
<SESLN> SESLOC



Response phase
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ControllingFloodRescue
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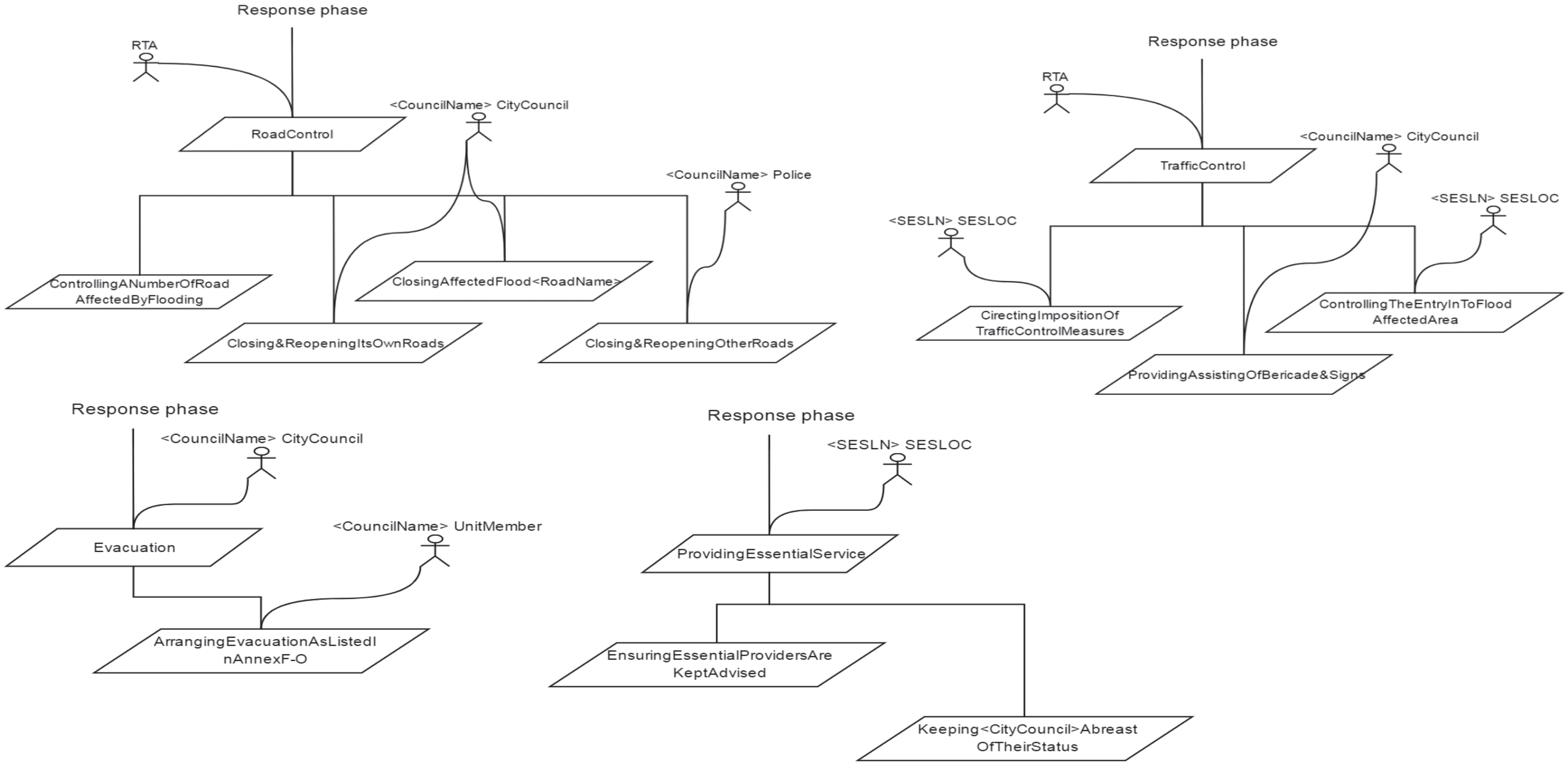
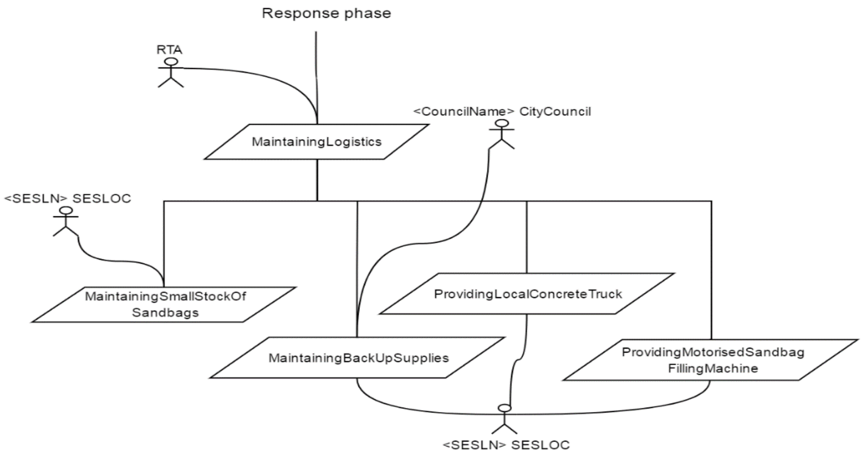
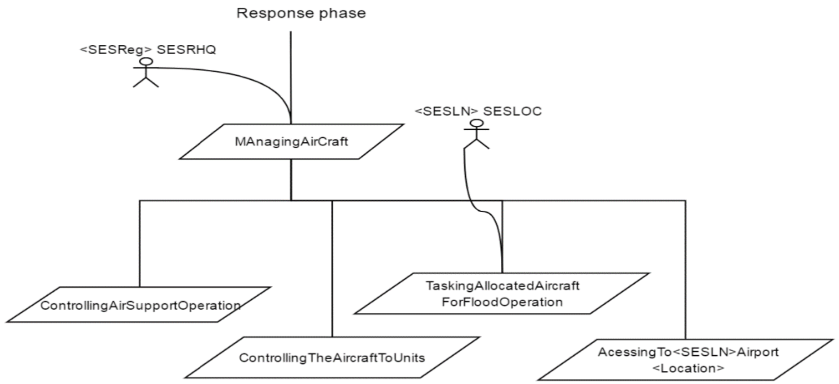
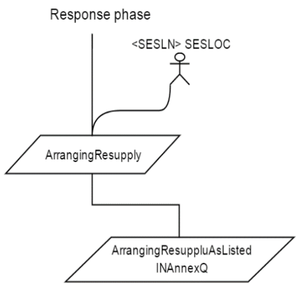
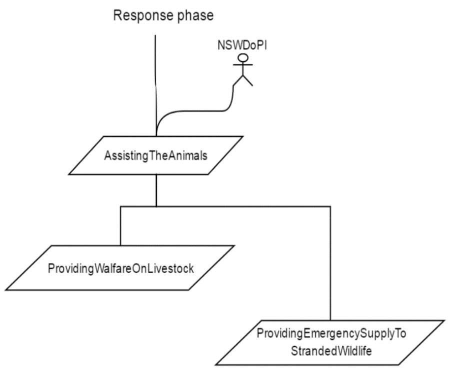
RTA
<CouncilName> CC
<SESLN> SESLOC
IssuingFloodBulletin
MaintainingPreWrittenFlood Bulletin
ProvidingPhone-InInformation ServiceForProtectingProperty
Ensuring<SESReg>IsRegularly Briefed
ProvidingInformationOn CurrentWarning
ProtectingAdviseSafetyFor PreotectingProperty
ProvidingPhone-InInformation ServiceForCurrentFlood
ProvidingCollation&DisseminationofRoadInformation
ProvidingCurrentFloodHeight &Behaviour
ProvidingDetailConditionOf MainRoads
ProvidingRoadStatusReportTo <SESReg>SESRHQ& <CouncilName> PLACHQ
ProvidingPhone-InService ToPublic
SeekingRoadStatusReport ForMainRoad
DistributingMainRoadInformation
<SESReg> SESRHQ

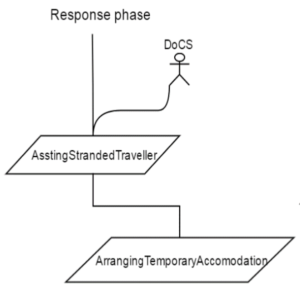

Response phase
RTA
RoadControl
<CouncilName> CityCouncil
<CouncilName> Police
ControllingANumberOfRoad AffectedByFlooding
ClosingAffectedFlood<RoadName>
Closing&ReopeningItsOwnRoads
Closing&ReopeningOtherRoads
Response phase
RTA
TrafficControl
<CouncilName> CityCouncil
<SESLN> SESLOC
<SESLN> SESLOC
CirectingImpositionOf TrafficControlMeasures
ControllingTheEntryInToFlood AffectedArea
ProvidingAssistingOfBericade&Signs
Response phase
<CouncilName> CityCouncil
Evacuation
<CouncilName> UnitMember
ArrangingEvacuationAsListedI nAnnexF-O
Response phase
<SESLN> SESLOC
ProvidingEssentialService
EnsuringEssentialProvidersAre KeptAdvised
Keeping<CityCouncil>Abreast OfTheirStatus

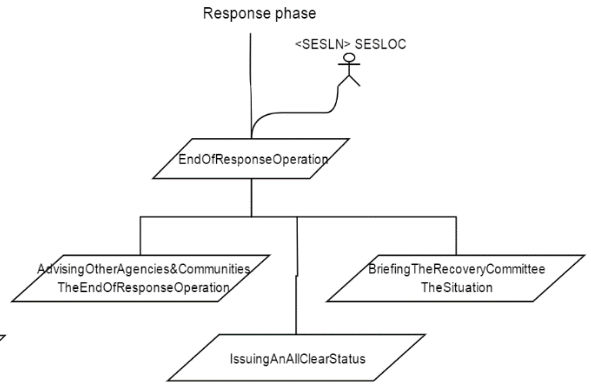

Response phase
RTA
MaintainingLogistics
<CouncilName> CityCouncil
<SESLN> SESLOC
MaintainingSmallStockOf Sandbags
ProvidingLocalConcreteTruck
MaintainingBackUpSupplies
ProvidingMotorisedSandbag FillingMachine
<SESLN> SESLOC


Response phase
<SESReg> SESRHQ
MAnagingAirCraft
<SESLN> SESLOC
ControllingAirSupportOperation
TaskingAllocatedAircraft ForFloodOperation
ControllingTheAircraftToUnits
AcessingTo<SESLN>Airport <Location>


Response phase
<SESLN> SESLOC
ArrangingResupply
ArrangingResuppluAsListed INAnnexQ


Response phase
NSWDoPI
AssistingTheAnimals
ProvidingWalfareOnLivestock
ProvidingEmergencySupplyTo StrandedWildlife


Response phase
DoCS
AsstingStrandedTraveller
ArrangingTemporaryAccomodation


Response phase
<SESLN> SESLOC
EndOfResponseOperation
AdvisingOtherAgencies&Communities TheEndOfResponseOperation
BriefingTheRecoveryCommittee TheSituation
IssuingAnAllClearStatus

2. *Customised role model of the SES NSW DISPLAN template*

DM Plan	*Customised role model* of the SES NSW DISPLAN template
Country	Australia
Disaster Type	Flood
Phase	Response phase

Role ID	R1
Name	**SES NSW**
Description	State Emergency Service (SES) New South Wales State
Responsibilities	1. Coordination of other agencies for flood management tasks 2. Organizing other agencies for flood management tasks 3. Operates after hours duty officer system whenever flood operations are not being conducted 4. Provides liaison (including a liaison officer (LO) SESNSW where necessary) to the <SESLN> SES Operations Centre (WWSESEOC) 5. The LO SESNSW to deploy resources of its parent organisations 6. LO SESNSW to deploy resources of its parent organisations 7. The LO <AgencyName> advises the <SESLN> SES LOC on resource availability for their service 8. The LO SESNSW provides communications to their own organisations SESNSW. 9. Provides the primary mean communications to and between deployed SESNSW resources by mobile phone and <SESLN> SESLOC UHF radio network 10. Active Reconnaissance to provide Flood Intelligent (FI) sources by monitoring the <LocalArea> areas. 11. Issue Local Flood Advices for the gauges listed in Annex C to SES Flood bulletin 12. Issues Evacuation Warnings as in Annex E
Constraints	-

Role ID	R2
Name	**<SESLN> SESLHQ**
Description	<SESLN> SES Local Headquarter
Responsibilities	1. Provides liaison (including a LO where necessary) to the <SESLN>SES Operations Centre 2. The LO <SESLN> SESLHQ to deploy resources of its parent organisations 3. Request a LO <SESLN> SESLHQ to deploy resources of its parent organisations 4. The LO <SESLN> SESLHQ advises the <SESLN> SESLOC on resource availability for their service 5. The LO <SESLN> SESLHQ provides communications to their own organisations 6. Provides communications as necessary to its deployed field team 7. Provides advice to the <SESReg> SESDHQ on current and expected impacts of flooding 8. Coordinates the delivery of warnings to the community by doorknocking, telephone, mobile public address systems, local radio stations and two-way radio 9. Confirmation of evacuation actions 10. Arranges The <SESReg> SESDHQ to issue warning information in the form of SES Division Flood Bulletins to media organisations and agencies listed in Annex D 11. Arranges <SESLN> SESLOC to advises the <SESReg> SESDHQ which will issue SES Livestock and Equipment Warnings to radio stations as indicated in Annex D 12. Maintains a list of landholders along the (Regional> River and its tributaries 13. Issues Bureau of Meteorology (BoM) Flood Watches that will be incorporated in <SESLN>SESLOC Flood Bulletins to radio stations by the <SESReg> SESDHQ 14. Issues Bureau of Meteorology (BoM) Flood Warnings for the locations detailed in Annex C 15. Advises response operation to the <CityName> City Council and the <CityName> CCLEOC. 16. Provides the <SESReg> SESDHQ with information for inclusion in SES Flood Bulletins on the estimated impacts of flooding at the predicted heights 17. Provides Bureau of Meteorology (BoM) Severe Weather Flash flooding possibilities as a result of intense rainfall 18. Issues Bureau of Meteorology (BoM) Severe weather warnings for flash flooding that will be incorporated into SES Flood Bulletins issued by the <SESReg> SESDHQ 19. Issue Local Flood Advices for the gauges listed in Annex C to SES Flood bulletin 20. Issues Evacuation Warnings as in Annex E 21. Issue <DamName> Dam-Failure Warnings to media outlets by the <SESReg> 22. Applies special arrangements in the case of severe flooding that may have the potential to cause the failure of <DamName> 23. Plays Standard Emergency Warning Signal (SEWS) over radio and television stations to alert communities to Evacuation Warnings, Special Warnings or Dam-Failure Warnings

	24. Approval to use the signal will be obtained from the <SESReg> SESDHQ 25. Provides a 'phone-in' information service for the community in relation to current warnings, river heights, flood behaviour, road conditions and closures of local and main roads 26. Provides a 'phone-in' information service for the community in relation to advice on safety matters and means of protecting property 27. Maintains a small stock of sandbags 28. Maintains back-up supplies 29. Provides a motorised sandbag-filling machine 30. Provides local concrete trucks
Constraints	-

Role ID	R3
Name	**<SESLN> SESLOC**
Description	<SESLN> SES Local Operational Controller
Responsibilities	1. Maintains The <SESLN> City Council Emergency Operations Centre (CCEOC) is located at <LocationAddress> 2. Operates after hours duty officer system whenever flood operations are not being conducted provide liaison (including a liaison officer where necessary) to the <SESLN>SES Emergency Operations Centre (SESEOC) 3. Request to provide liaison (including a liaison officer where necessary) to the <SESLN> SES Operations Centre 4. Provides liaison (including a LO <SESLN> SESLOC where necessary) to the <SESLN>SES Operations Centre 5. The LO <SESLN> SESLOC to deploy resources of its parent organisations 6. Request a LO <SESLN> SESLOC to deploy resources of its parent organisations 7. The LO <SESLN> SESLOC advises the <SESLN> SES Local Controller on resource availability for their service 8. The LO <SESLN> SESLOC provides communications to their own organisations 9. Provides the primary mean communications to and between deployed SES resources by mobile phone and local <SESLN> SES UHF radio network 10. Provides communications as necessary to its deployed field team 11. Provides back-up communication means 12. Activated by contacting with the Bureau of Meteorology (BoM) to discuss the development of flood warnings which will normally be through the <SESReg> SESDHQ 13. Contacting with the Bureau of Meteorology (BoM) to discuss the development of flood warnings 14. Assures <SESReg> SESDHQ To contact Bureau of Meteorology (BoM) to discuss the development of flood warnings 15. Advising certain persons and organizations to initiate response operation for flooding anticipated response 16. Initiate response operation regardless of the location and severity of the flooding anticipated 17. Advising other agencies listed in this plan to start response operation 18. Request to advise other organizations to initiate response operation (as listed in this DM plan) as appropriate to the location and nature of the threat 19. Provides Flood Watches, which give an early appreciation of developing meteorological situations that could lead to flooding 20. Provides Flood Warnings, which include river height readings and height-time predictions as listed in Annex C 21. Provides Severe Weather Warnings for Flash Flooding 22. Provides Key gauge level information that is available from the BoM website 23. Provides information on flooding and its consequences, including those in nearby council areas 24. Advises of road closures within the council area 25. Provides information on <DamName> Dams and the likely effects of failure 26. Provides storage level information on <DamName> Dam 27. Advise flow rates and rates of rise for the <Regional> River that are available on-line at http://waterinfo.dlwc.nsw.gov.au/riis/drr/index.html 28. Active Reconnaissance to provide Flood Intelligent (FI) sources by monitoring the <Local> areas 29. Ensure that resources are in place for the distribution of foodstuffs and medical supplies to the areas that could become isolated 30. Advise appropriate agencies so that resources (including sandbags, fire-fighting appliances, ambulances, etc.) are deployed to ensure that operational capability is maintained 31. Advise emergency services and essential agencies located on the floodplain to relocate resources to flood free locations 32. Provides the <SESReg> MSESDHQ with information for inclusion in SES Flood Bulletins on the estimated impacts of flooding at the predicted heights 33. Issue Local Flood Advices for the gauges listed in Annex C to SES Flood bulletin 34. Issues Evacuation Warnings as in Annex E

	35. Provides road status reports for main roads in the council area to the <SESReg> SESDHQ Road Information Cell (SESDHQRIC) and to the <LocalPolice> Police Local Area Command Headquarters (PLACHQ) 36. Obtains road status reports for main roads in the council area information from the <LocalPolice> Police, <CouncilName> and RTA 37. Ensures that the <SESReg> SESDHQ is regularly briefed on the progress of operations and on future resource needs 38. Directs the imposition of traffic control measures 39. Controls the entry into flood affected areas 40. Carries out flood rescue using high clearance vehicles, flood boats and (under some circumstances) helicopters 41. Request additional flood boats and crews through the <SESReg> SESDHQ 42. Provides Essential Services 43. Ensure that the providers of essential services (electricity, water, sewerage, medical and public health) are kept advised of the flood situation 44. Essential service providers must keep the <SESLN> SES Local Operational Controller abreast of their status and ongoing ability as listed in Annex B 45. Task aircraft allocated by the <SESReg> SESDHQ for flood operations within the <council area> 46. Arranges resupply as detailed in Annex Q 47. Advises other agencies and the community The end of response operation 48. Issue an ‘all clear’ for evacuees to return to their homes 49. Briefs the recovery committee on the situation and any need
Constraints	1. Preliminary deployments may be required for up to one week 2. In the event of major flooding, the <SESLN> SES Local Controller may direct the imposition of traffic control measures 3. The entry into flood affected areas will be controlled in accordance with the provisions of the State Emergency Service Act, 1989 (Part 5, Sections 19, 20, 21 and 22) and the State Emergency Rescue Management Act, 1989 (Part 4, Sections 60KA, 60L and 61) 4. Aircraft can be used for a variety of purposes during flood operations, however, should only be used if other transport means are not available or not suitable 5. The <SESLN> SES Local Controller may task aircraft allocated by the <SESReg> SESDHQ for flood operations within the council area 6. Air support operations will be conducted under the control of the <SESReg> SESDHQ, which may allocate aircraft to units if applicable

Role ID	R4
Name	**<SESReg> SESDHQ**
Description	**<SESReg> State Emergency Service Division Headquarters**
Responsibilities	1. Provides liaison (including a LO <SESReg> SESDHQ where necessary) to the <SESLN> SES Operations Centre 2. The LO <SESReg> SESDHQ to deploy resources of its parent organisations 3. Request a LO <SESReg> SESDHQ to deploy resources of its parent organisations 4. The LO <SESReg> SESDHQ advises the <SESLN> SES Local Controller on resource availability for their service 5. The LO <SESReg> SESDHQ provides communications to their own organisations 6. Provides communications as necessary to its deployed field team 7. Assures <SESReg> SESDHQ To contact Bureau of Meteorology (BoM) to discuss the development of flood warnings 8. Provides information on flooding and its consequences, including those in nearby council areas 9. Provides advice to the <SESReg> SESDHQ on current and expected impacts of flooding 10. Arranges The <SESReg> SESDHQ to issue warning information in the form of <SESLN> SESLOC Division Flood Bulletins to media organisations and agencies listed in Annex D 11. Arranges <SESLN> SES Local Controller to advises the <SESReg> SESDHQ which will issue SES Livestock and Equipment Warnings to radio stations as indicated in Annex D 12. Provides Bureau of Meteorology (BoM) Severe Weather Flash flooding possibilities as a result of intense rainfall 13. Issues Bureau of Meteorology (BoM) Severe weather warnings for flash flooding that will be incorporated into <SESLN> SESLOC Flood Bulletins issued by the <SESReg> SESDHQ 14. Applies special arrangements in the case of severe flooding that may have the potential to cause the failure of <DamName> Dam 15. Issue <DamName> Dam-Failure Warnings to media outlets by the <SESReg> SESDHQ 16. Plays Standard Emergency Warning Signal (SEWS) over radio and television stations to alert communities to Evacuation Warnings, Special Warnings or <DamName> Dam-Failure Warnings 17. Approval to use the signal will be obtained from the <SESReg> SESDHQ

	18. Provides Current warnings, together with indications of the likely impact of flooding at any predicted heights to media outlets and agencies 19. Provides Current flood heights and flood behaviour to media outlets and agencies 20. Provides Details of conditions and closures of main roads to media outlets and agencies 21. Provides Advice on safety matters and means of protecting property to media outlets and agencies 22. Maintains pre-written flood bulletins for key heights 23. Provides a ‘phone-in’ information service for the community in relation to current warnings, river heights, flood behaviour, road conditions and closures of local and main roads 24. Provides a ‘phone-in’ information service for the community in relation to advice on safety matters and means of protecting property 25. Provides collation and dissemination of road information 26. Provides road status reports for main roads in the council area to the <SESReg> SESDHQ Road Information Cell (SESDHQRIC) and to the <LocalPolice> Police Local Area Command Headquarters (PLACHQ) 27. Obtains road status reports for main roads in the council area information from the Police, Council and RTA 28. Distributes information on main roads to <SESLN> SES units, media outlets and agencies as part of SES Flood Bulletins 29. Provides a ‘phone-in’ service to the public Collation and dissemination of road information 30. Ensures that the <SESReg> SESDHQ is regularly briefed on the progress of operations and on future resource needs 31. Request additional flood boats and crews through the <SESReg> SESDHQ 32. Maintains back-up supplies 33. Provides local concrete trucks 34. Provides a motorised sandbag-filling machine 35. Controls Air support operations 36. Controls the allocation of aircraft to units 37. Task aircraft allocated by the <SESReg> SESDHQ for flood operations within the <CouncilName> council area 38. Accesses to the <LocalAirport> Airport 39. Issues warning information in the form of <SESLN> SES Division Flood Bulletins to media organisations and agencies listed in Annex D 40. Issue SES Livestock and Equipment Warnings to radio stations as indicated in Annex D 41. Maintains a list of landholders along the <Regional> River and its tributaries 42. Releases to radio stations BoM Flood Watches that will be incorporated in <SESLN> SES Flood Bulletins 43. Provides a warning of the possibility for BoM Severe Weather Warnings for Flash Flooding as a result of intense rainfall. This product may be issued concurrently with flood warnings and flood watches. Severe weather warnings for flash flooding will be incorporated into <SESLN> SES Flood Bulletins 44. Issues <DamName> Dam failure warnings to media outlets issues <SESLN> SES Flood Bulletins to media outlets and agencies on behalf of all <SESLN> SES units in the Division 45. Maintains pre-written flood bulletins for key heights 46. Distributes information on main roads to <SESLN> SES units, media outlets and agencies as part of SES Flood Bulletins 47. Controlling the use of aircraft in a variety of purposes during flood operations including evacuation, rescue, re-supply, reconnaissance and emergency travel 48. Provide a liaison officer, where necessary, to the <SESLN> SES Operations Centre
Constraints	1. Aircraft can be used for a variety of purposes during flood operations, however, should only be used if other transport means are not available or not suitable 2. The <SESLN> SES Local Controller may task aircraft allocated by the <SESReg> SESDHQ for flood operations within the <CouncilName> council area 3. Air support operations will be conducted under the control of the <SESReg> SESDHQ, which may allocate aircraft to units if applicable

Role ID	R5
Name	**BoM**
Description	Bureau of Meteorology of Australia
Responsibilities	1. Provides Flood Watches, which give an early appreciation of developing meteorological situations that could lead to flooding 2. Provides Flood Warnings, which include river height readings and height-time predictions as listed in Annex C 3. Provides Severe Weather Warnings for Flash Flooding 4. Provides Key gauge level information that is available from the BoM website 5. Assures <SESReg> SESDHQ to contact BoM to discuss the development of flood warnings
Constraints	-

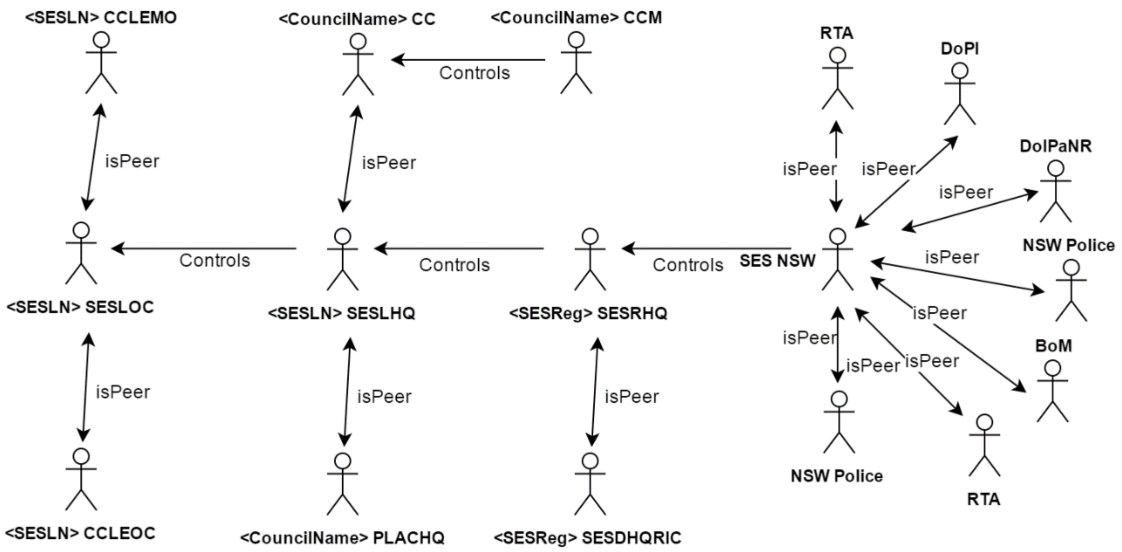
Role ID	R6
Name	**<CouncilName> CC**
Description	<CouncilName> City Council
Responsibilities	1. Provides liaison (including a LO <CouncilName> City Council where necessary) to the <SESLN> SES Operations Centre 2. The LO <CouncilName> City Council to deploy resources of its parent organisations 3. Request a LO <CouncilName> City Council to deploy resources of its parent organisations 4. The LO <CouncilName> City Council advises the <SESLN> SESLOC on resource availability for their service 5. The LO <CouncilName> City Council provides communications to their own organisations 6. Provides communications as necessary to its deployed field team 7. Advises of road closures within the council area 8. Advises response operation to the <CouncilName> CC and the <LocalName> City Council Local Emergency Operations Controller (CCLEOC) 9. Provides road status reports for main roads in the council area to the <SESReg> Road Information Cell (SESDHQRIC) and to the <LocalPolice> Police Local Area Command Headquarters (PLACHQ) 10. Obtains road status reports for main roads in the council area information from the <LocalPolice> Police, <CouncilName> Council and RTA 11. Closes and re-opens its own roads 12. Closes the <LocalHighWayName> within the urban centre of <LocalName> as effected by flooding 13. Provides assistance in the erection of barricades and signs 14. Arrangements evacuation for the <CouncilName> City Council area as listed in Annexes F to O
Constraints	-

Role ID	R7
Name	**<CouncilName> CCLEMO**
Description	<CouncilName> City Council Local Emergency Management Officer
Responsibilities	1. Provides liaison (including a LO <CouncilName> CCLEMO where necessary) to the <SESLN> SES Operations Centre 2. The LO <CouncilName> CCLEMO to deploy resources of its parent organisations 3. Request a LO <CouncilName> CCLEMO to deploy resources of its parent organisations 4. The LO <CouncilName> CCLEMO advises the <SESLN> SESLOC on resource availability for their service 5. The LO <CouncilName> CCLEMO provides communications to their own organisations 6. Provides communications as necessary to its deployed field team 7. Initiate response operation regardless of the location and severity of the flooding anticipated 8. Advising other agencies listed in this plan to start response operation 9. Request to advise other organizations to initiate response operation (as listed in this DM plan) as appropriate to the location and nature of the threat
Constraints	-

Role ID	R8
Name	**<CouncilName> CCLEOC**
Description	<CouncilName> City Council Local Emergency Operation Controller
Responsibilities	1. Provides liaison (including a LO <CouncilName> City Council LEOC where necessary) to the <SESLN> SES Operations Centre 2. The LO <CouncilName> City Council LEOC to deploy resources of its parent organisations 3. Request a LO <CouncilName> City Council LEOC to deploy resources of its parent organisations 4. The LO <CouncilName> City Council LEOC advises the <SESLN> SESLOC on resource availability for their service 5. The LO <CouncilName> City Council LEOC provides communications to their own organisations 6. Provides communications as necessary to its deployed field team 7. Initiate response operation regardless of the location and severity of the flooding anticipated 8. Advises response operation to the <CouncilName> City Council and the <CouncilName> City Council LEOC (CCLEOC)
Constraints	-

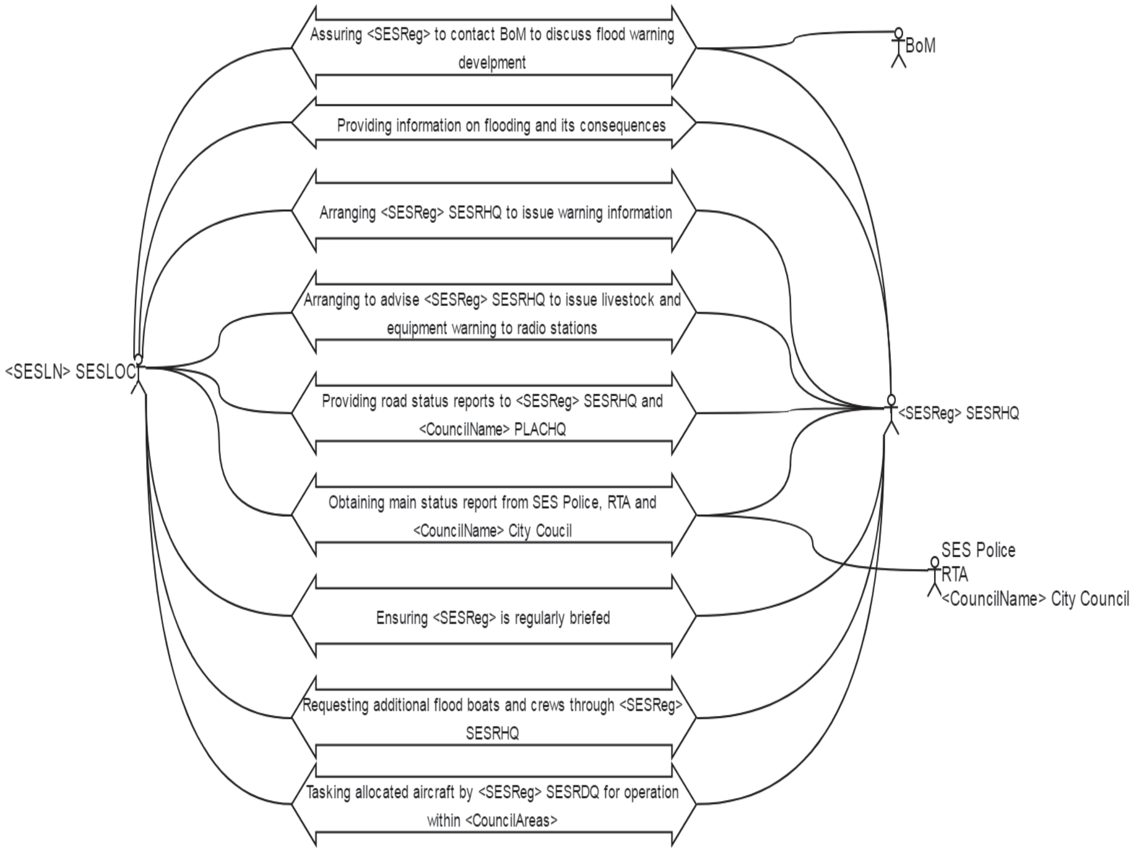
3. *Customised organisation model of the SES NSW DISPLAN template*

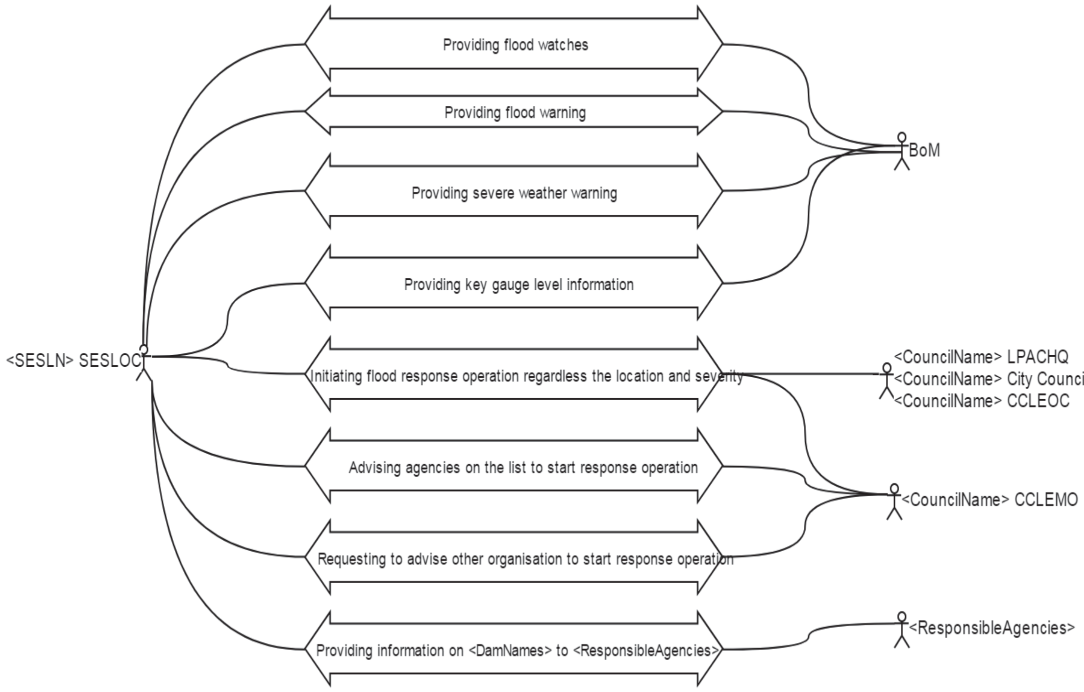
DM Plan	*Customised organisation model* of the SES NSW DISPLAN template
Country	Australia
Disaster Type	Flood
Phase	Response phase

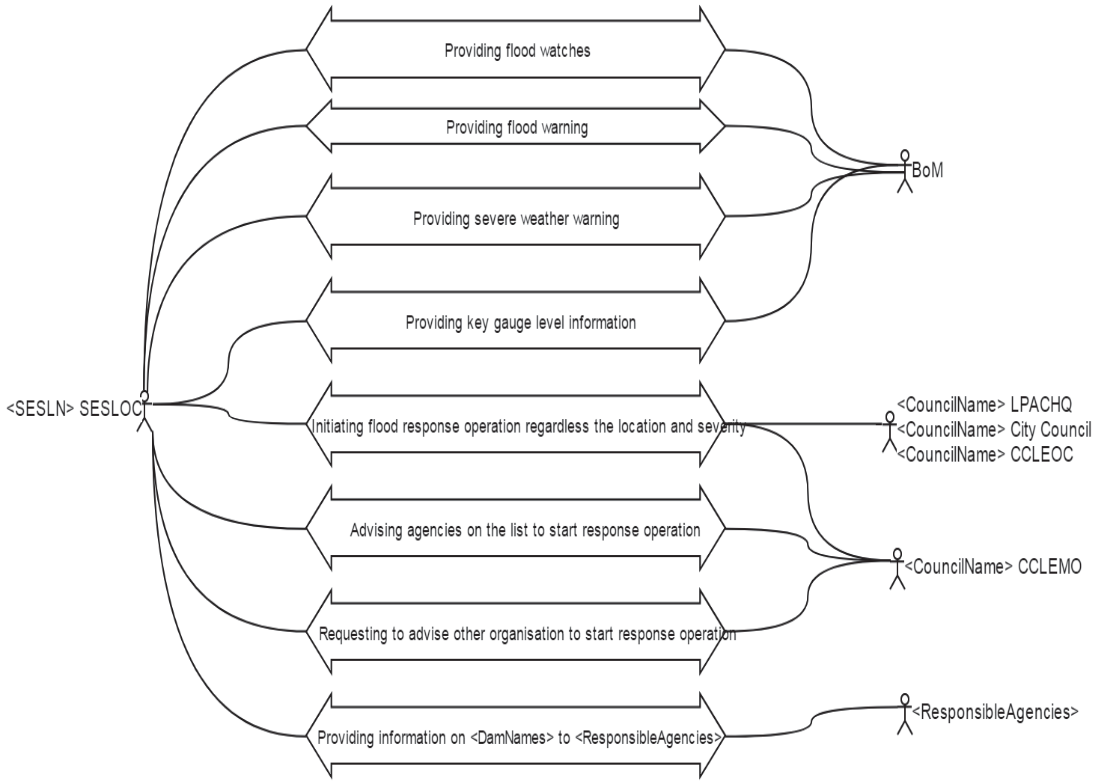


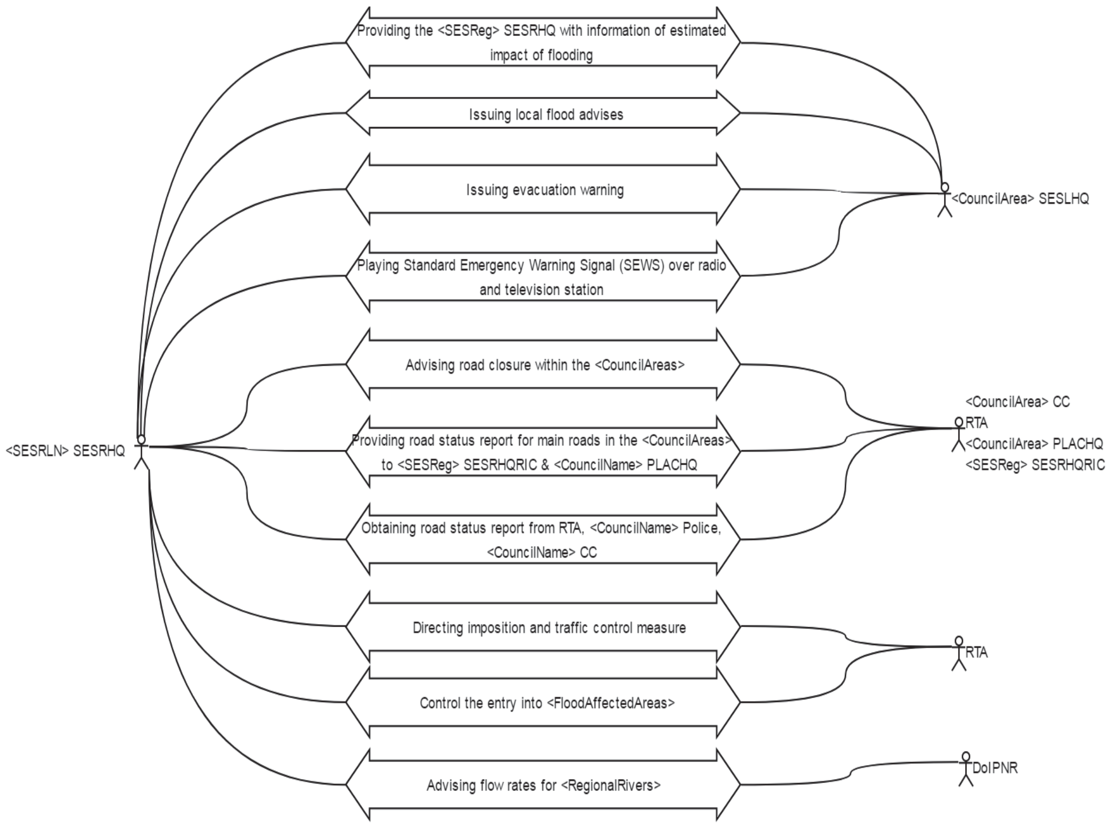
4. *Customised interaction model of the SES NSW DISPLAN template*

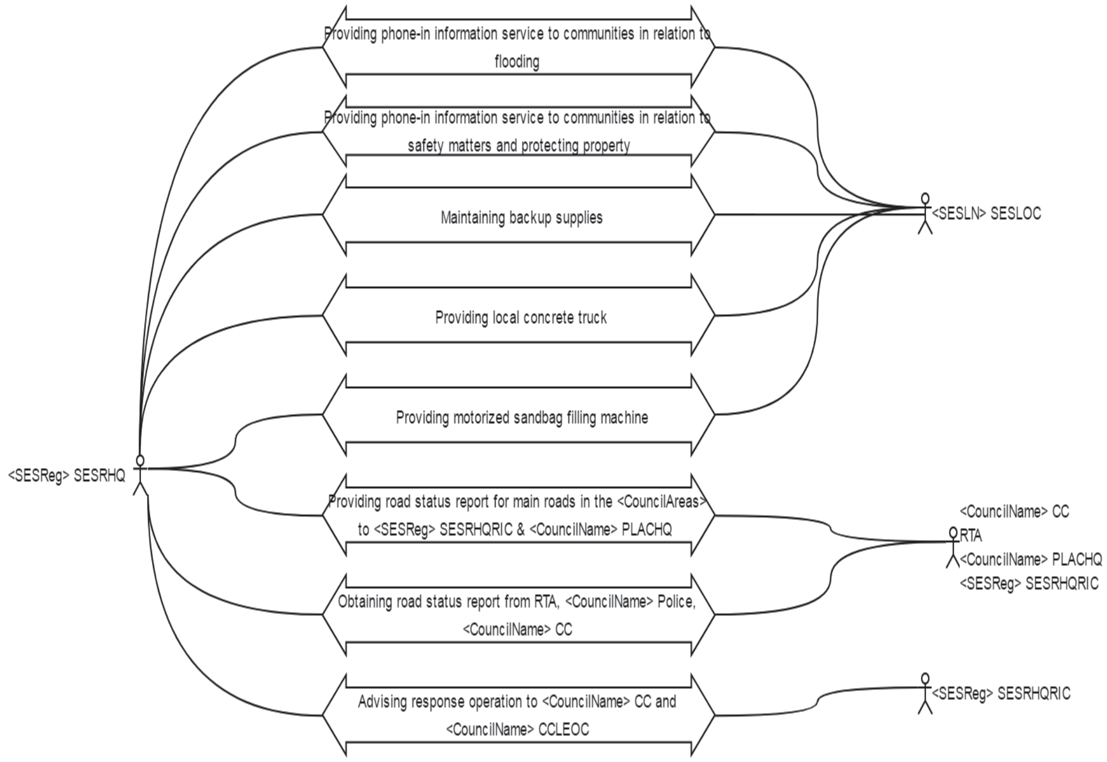
DM Plan	*Customised interaction model* of the SES NSW DISPLAN template
Country	Australia
Disaster Type	Flood
Phase	Response phase

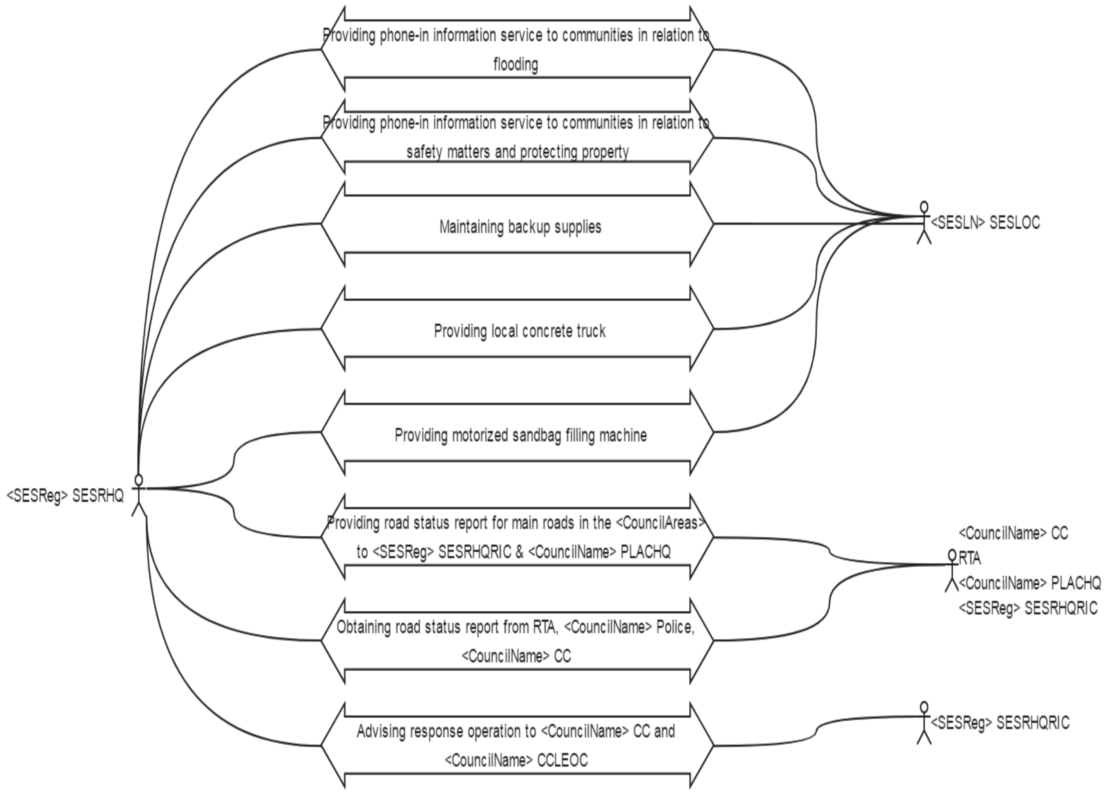

Assuring <SESReg> to contact BoM to discuss flood warning develpment
Providing information on flooding and its consequences
Arranging <SESReg> SESRHQ to issue warning information
Arranging to advise <SESReg> SESRHQ to issue livestock and equipment warning to radio stations
Providing road status reports to <SESReg> SESRHQ and <CouncilName> PLACHQ
Obtaining main status report from SES Police, RTA and <CouncilName> City Coucil
Ensuring <SESReg> is regularly briefed
Requesting additional flood boats and crews through <SESReg> SESRHQ
Tasking allocated aircraft by <SESReg> SESRDQ for operation within <CouncilAreas>
<SESLN> SESLOC
BoM
<SESReg> SESRHQ
SES Police
RTA
<CouncilName> City Council


Providing flood watches
Providing flood warning
Providing severe weather warning
Providing key gauge level information
Initiating flood response operation regardless the location and severity
Advising agencies on the list to start response operation
Requesting to advise other organisation to start response operation
Providing information on <DamNames> to <ResponsibleAgencies>
<SESLN> SESLOC
BoM
<CouncilName> LPACHQ
<CouncilName> City Council
<CouncilName> CCLEOC
<CouncilName> CCLEMO
<ResponsibleAgencies>


Providing flood watches
Providing flood warning
Providing severe weather warning
Providing key gauge level information
Initiating flood response operation regardless the location and severity
Advising agencies on the list to start response operation
Requesting to advise other organisation to start response operation
Providing information on <DamNames> to <ResponsibleAgencies>
<SESLN> SESLOC
BoM
<CouncilName> LPACHQ
<CouncilName> City Council
<CouncilName> CCLEOC
<CouncilName> CCLEMO
<ResponsibleAgencies>


Providing the <SESReg> SESRHQ with information of estimated impact of flooding
Issuing local flood advises
Issuing evacuation warning
Playing Standard Emergency Warning Signal (SEWS) over radio and television station
Advising road closure within the <CouncilAreas>
Providing road status report for main roads in the <CouncilAreas> to <SESReg> SESRHQRIC & <CouncilName> PLACHQ
Obtaining road status report from RTA, <CouncilName> Police, <CouncilName> CC
Directing imposition and traffic control measure
Control the entry into <FloodAffectedAreas>
Advising flow rates for <RegionalRivers>
<SESRLN> SESRHQ
<CouncilArea> SESLHQ
<CouncilArea> CC
RTA
<CouncilArea> PLACHQ
<SESReg> SESRHQRIC
RTA
DoIPNR


Providing phone-in information service to communities in relation to flooding
Providing phone-in information service to communities in relation to safety matters and protecting property
Maintaining backup supplies
Providing local concrete truck
Providing motorized sandbag filling machine
Providing road status report for main roads in the <CouncilAreas> to <SESReg> SESRHQRIC & <CouncilName> PLACHQ
Obtaining road status report from RTA, <CouncilName> Police, <CouncilName> CC
Advising response operation to <CouncilName> CC and <CouncilName> CCLEOC
<SESReg> SESRHQ
<SESLN> SESLOC
<CouncilName> CC
RTA
<CouncilName> PLACHQ
<SESReg> SESRHQRIC
<SESReg> SESRHQRIC


Providing phone-in information service to communities in relation to flooding
Providing phone-in information service to communities in relation to safety matters and protecting property
Maintaining backup supplies
Providing local concrete truck
Providing motorized sandbag filling machine
Providing road status report for main roads in the <CouncilAreas> to <SESReg> SESRHQRIC & <CouncilName> PLACHQ
Obtaining road status report from RTA, <CouncilName> Police, <CouncilName> CC
Advising response operation to <CouncilName> CC and <CouncilName> CCLEOC
<SESReg> SESRHQ
<SESLN> SESLOC
<CouncilName> CC
RTA
<CouncilName> PLACHQ
<SESReg> SESRHQRIC
<SESReg> SESRHQRIC

5. *Customised environment model of the SES NSW DISPLAN template*

DM Plan	*Customised environment model* of the SES NSW DISPLAN template
Country	Australia
Disaster Type	Flood
Phase	Response phase

E1	**Agencies and organizations**	
Name	Agencies and organizations	
Environment Entity ID	E1	
Description	Agencies and organisations for flood management tasks to be coordinated	
Attributes	#	Unique number distinguishing inputted data
	Type	Type agencies/organization
	Scope	Local/National
	Phone number	Phone number to be contacted
	Mobile number	Mobile number to be contacted
Roles Involved	<SESLN> SESLC	
	MSESDHQ	
	<CouncilName> CC	
	<SESLN> UM	
	<SESLN> LEMO	
	<CouncilName> CCM	
	<SESLN> CLEOP	
	<LocalPolice> Police NSW	
	<SESLN> LEOCON	
	<SESLN> NSWFB	
	RFS	
	VRA	
	DoPI	
	DoCS	
	ASoNSW	
	RailCorp	
	TSC	
	DoEaT	
	<SESLN> CEO	
	<CouncilName> PSaCC	
	RARFC	
	CSU	
	<SESLN> SESFW	

E2	**Communications**	
Name	Communications	
Environment Entity ID	E2	
Description	Liaison officers are to be able to provide communications to their own organisations	
Attribute	#	Unique number distinguishing inputted data
	Type of communications	Radio UHF/Mobile phone, etc.
Roles Involved	<SESLN> SESLC	
	LOs	
	<SESReg> SESDHQ	
	<CouncilName> CC	
	<SESLN> UM	
	<SESLN> LEMO	
	<CouncilName> CCM	
	<SESLN> CLEOP	
	<LocalPolice> Police NSW	
	<SESLN> UM	
	<SESLN> LEOCON	
	RFS	
	PSaCC	
	RARFC	
	CSU	

	SESFW

E3	**Other agencies**	
Name	Other agencies	
Environment Entity ID	E3	
Description	Other agencies listed in this plan will be advised to start respond operation of flood	
Attribute	#	Unique number distinguishing inputted data
	List name	Nama of agencies involved in
Roles Involved	<SESLN> SESLC	
	<SESLN> LEMO	

E4	**The Gauges**	
Name	The Gauges	
Environment Entity ID	E4	
Description	The gauges for which predictions are provided for are listed in Annex C	
Attribute	#	Unique number distinguishing inputted data
	Gauge Names	Gauge names
Roles Involved	<SESLN> SESLC	
	BoM	

E5	**Resources for distribution**	
Name	Resources for distribution	
Environment Entity ID	E5	
Description	<SESLN> SES Local Controller will ensure that resources are in place for the distribution of foodstuffs and medical supplies to the areas that could become isolated	
Attribute	#	Unique number distinguishing inputted data
	Type of resources	Type of resources
	Availability	Yes/No
Roles Involved	<SESLN> SESLC	

E6	**Appropriate agencies**	
Name	**Appropriate agencies**	
Environment Entity ID	E6	
Description	Appropriate agencies will be advised When towns and villages are expected to become isolated to deploy resources (including sandbags, firefighting appliances, ambulances, etc.). Pre-deployments may be required for up to one week	
Attribute	#	Unique number distinguishing inputted data
	Type	Type agencies/organization
	Scope	Local/National
Roles Involved	<SESLN> SESLC	

E7	**Resources to be deployed**	
Name	Resources to be deployed	
Environment Entity ID	E7	
Description	Resources (including sandbags, firefighting appliances, ambulances, etc.), when towns and villages are expected to become isolated, are deployed to ensure that operational capability is maintained. Pre-deployments may be required for up to one week	
Attribute	#	Unique number distinguishing inputted data
	Type of resources	Type of resources
	Availability	Yes/No
Roles Involved	SESLC	

E8	**Emergency Service**	
Name	Resources to be deployed	
Environment Entity ID	E8	
Description	Resources (including sandbags, firefighting appliances, ambulances, etc.), when towns and villages are expected to become isolated, are deployed to ensure that operational capability is maintained. Pre-deployments may be required for up to one week	
Attribute	#	Unique number distinguishing inputted data
	Type of services	Type of service
	Communication type	Mean to communicated with
	Contact number	Contact number
Roles Involved	<SESLN> SESLC	

E9	**Essential agencies**	
Name	Resources to be deployed	
Environment Entity ID	E9	
Description	Resources (including sandbags, firefighting appliances, ambulances, etc.), when towns and villages are expected to become isolated, are deployed to ensure that operational capability is maintained. Pre-deployments may be required for up to one week	
Attribute	#	Unique number distinguishing inputted data
	Type	Type agencies/organization
	Scope	Local/National
	Contact number	Contact number
Roles Involved	<SESLN> SESLC	

E10	**Media organizations and agencies**	
Name	**Media organizations agencies**	
Environment Entity ID	E10	
Description	Media organisations and agencies listed in Annex D	
Attribute	#	Unique number distinguishing inputted data
	Type	TV/Radio etc.
	Scope	Local/National
	Contact number	Contact number
Roles Involved	<SESLN> SESLC	
	<SESReg> SESDHQ	

E11	**List of Landholders**	
Name	List of landholders	
Environment Entity ID	E11	
Description	List of landholders along the Murrumbidgee River and its tributaries	
Attribute	#	Unique number distinguishing inputted the data
	Name	Name of the landholder
	Address	Address
	Contact number	Contact numbers to reach them
Roles Involved	<SESLN> SESLC	
	<SESReg> SESDHQ	
	<SESLN> SESLHQ	

E12	**Flood watch**	
Name	Flood watch	
Environment Entity ID	E12	
Description	Flood Watches will be incorporated in SES Flood Bulletins released to radio stations If there are signs of impending floods	
Attribute	#	Unique number distinguishing inputted data
	Forecast to flood	Prediction analysis of flood disaster
Roles Involved	<SESLN> SESLC	
	<SESReg> SESDHQ	

E13	**Flash flood**	
Name	Flash flood	
Environment Entity ID	E13	
Description	Provides a warning of the possibility for flash flooding as a result of intense rainfall. These warnings are issued when severe weather is expected to affect land based communities with 6 to 24 hours.	
Attribute	#	Unique number distinguishing inputted data
	Time prediction	TV/Radio etc.
	Impact to communities	Prediction of area of impacted communities
	Effects	Effect that will happen
Roles Involved	<SESLN> SESLC	
	<SESReg> SESDHQ	

E14	**Warning massage template for evacuation**
Name	Template Warning massage template for evacuation
Environment Entity ID	E14
Description	A template guide to the content of evacuation warning messages is at Annex E

Attribute	#	Unique number distinguishing inputted data
	Warning for	TV/Radio etc.
	Authorized by	Local/National
Roles Involved	<SESLN> SESLC	
	<SESReg> SESDHQ	

E15	**Detail arrangement for evacuation**	
Name	Detail arrangement for evacuation	
Environment Entity ID	E15	
Description	Special arrangements apply in the case of severe flooding that may have the potential to cause the failure of Burrinjuck, Talbingo and Blowering Dam. Details of these arrangements are described in Annex I	
Attribute	#	Unique number distinguishing inputted data
	Authorized by	Local/National
Roles Involved	<SESLN> SESLC	
	<SESReg> SESDHQ	

E16	**Dams Failure warning**	
Name	Dams Failure warning	
Environment Entity ID	E16	
Description	Details of these arrangements are described in Annex I. Dam failure warnings will be issued to media outlets by the Murrumbidgee SES Division Headquarters	
Attribute	#	Unique number distinguishing inputted data
	Authorized by	Local/National
Roles Involved	<SESLN> SESLC	
	<SESReg> SESDHQ	

E17	**Information of SES flood bulletin**	
Name	SES flood bulletin	
Environment Entity ID	E17	
Description	The Murrumbidgee SES Division Headquarters issues SES Flood Bulletins to media outlets and agencies on behalf of all SES units in the Division. SES Flood Bulletins contain the following information relating to all council areas in which flooding is occurring	
Attribute	#	Unique number distinguishing inputted data
	Type of warning	Local/National
	Flood heights and flood behavior	flood heights and flood behavior
	Flood and road condition	Details of conditions and closures of main roads
	Advice	Advice on safety matters and means of protecting property
Roles Involved	<SESLN> SESLC	
	<SESReg> SESDHQ	

E18	**Infrastructure list of possible risk**	
Name	Infrastructure list of possible risk	
Environment Entity ID	E18	
Description	Infrastructure at risk of flood damage as listed in Annex B	
Attribute	#	Unique number distinguishing inputted data
	Infrastructure name	Infrastructure name
Roles Involved	<SESLN> SESLC	
	<SESReg> SESDHQ	

E19	**Resupply arrangements**	
Name	Resupply arrangements	
Environment Entity ID	E19	
Description	Resupply arrangements are detailed in Annex Q	
Attribute	#	Unique number distinguishing inputted data
	Infrastructure name	Infrastructure name
Roles Involved	<SESLN> SESLC	

	<SESReg> SESDHQ

6. *Customised agent model of the SES NSW DISPLAN template*

DM Plan	*Customised agent model* of the SES NSW DISPLAN template
Country	Australia
Disaster Type	Flood
Phase	Response phase

Agent Type	<SESLN> SESNSW Type
Name	**<SESLN> SESNSW**
Description	Play role as the <SESLN> SES New State Wales
References	**R01**
Activity	**Activity Name :** Control Operation **Functionality :** Control Operation **Trigger :** Control of response operation **Action :** 1. Coordination of other agencies for flood management tasks 2. Organizing other agencies for flood management tasks
	Activity Name : Operate operation centre **Functionality :** Operate operation centre **Trigger :** Organizing response operation **Action :** Operates after hours duty officer system whenever flood operations are not being conducted
	Activity Name : Provide Flood Intelligence (FI) **Functionality :** Provide Flood Intelligence (FI) **Trigger :** Flood Intelligence (FI) gathering to response operation **Action :** Monitoring source of Flood Intelligence (FI) for the <LocalName> areas.
	Activity Name : Issuing warning **Functionality :** Issuing warning **Trigger :** Operate warning services **Action :** Issuing Local Flood Advices for the gauges listed in Annex C. These are issued in <SESReg> SESDHQ Flood Bulletins and/or direct from the <SESLN> SESLOC via facsimile
	Activity Name : Provide Liaison Officer (LO) **Functionality :** Provide Liaison Officer (LO) **Trigger :** At the request of SESLC **Action :** Provide a liaison officer, where necessary, to the <SESLN> SES Operations Centre
Environment Considerations	[E1] **Agencies and organizations**

Agent Type	<SESLN> SESLC Type
Name	**<SESLN> SESLC**
Description	Play role as the <SESLN> SES Local Controller
References	**R02**
Activity	**Activity Name :** Operate operation centre **Functionality :** Operate operation centre **Trigger :** 1. Operate operation center for response plan **Action :** Maintains an Operations Centre at <Localname> Road, <CouncilName>
	Activity Name : Request to provide LO **Functionality :** Request to provide LO **Trigger :** Control response operation **Action :** Request to provide liaison (including a liaison officer where necessary) to the <SESLN> SES Operations Centre
	Activity Name : Start of response operation **Functionality :** Start of response operation **Trigger :** 1. On receipt of a BoM Preliminary Flood Warning, Flood Warning, Flood Watch or Severe Weather Warning for Flash Flooding 2. On receipt of <DamName> dam-failure warnings 3. When other evidence leads to an expectation of flooding within the council area

Action :	1. Contact with the Bureau of Meteorology (BoM) to discuss the development of flood warnings which will normally be through the <SESReg> SESDHQ 2. Advising <SESLN> CCLEOC for flooding anticipated response (for transmission to the <LocalPolice> Police NSW Police Local Area Command Headquarters 3. Advising <SESLN> SESU to initiate response operation for flooding anticipated response 4. Advising <SESReg> SESDHQ to initiate response operation for flooding anticipated response 5. Advising <SESLN> CCLEMO to initiate response operation for flooding anticipated response 6. Advising <CouncilName> CCM to initiate response operation for flooding anticipated response 7. Request to advise other organizations to initiate response operation (as listed in this DM plan) for flooding anticipated response 8. Request to initiate response operation for flood anticipated based on appropriate of the location to other organizations as listed in this DM plan
Activity Name :	Preliminary deployments
Functionality :	Preliminary deployments
Trigger :	Preliminary deployments to start response operation
Action :	1. Ensuring that resources are in place for the distribution of foodstuffs and medical supplies to the areas that could become isolated 2. Advising appropriate agencies so that resources (including sandbags, firefighting appliances, ambulances, etc.) are deployed to ensure that operational capability is maintained. Pre-deployments may be required for up to one week
Activity Name :	Protection of resources
Functionality :	Protection of resources
Trigger :	Protection of resources of the response operation
Action :	Advising emergency services and essential agencies located on the floodplain to relocate resources to flood free locations
Activity Name :	<SESLN> SES livestock and equipment warning
Functionality :	<SESLN> SES livestock and equipment warning
Trigger :	Following heavy rain or when there are indications of significant creek or river rises (even to levels below Minor Flood heights)
Action :	Advising the <SESReg> SESDHQ to issue <SESLN> SES Livestock and Equipment Warnings to radio stations as indicated in Annex D
Activity Name :	BoM Flood Warning
Functionality :	BoM Flood Warning
Trigger :	On receipt BoM Flood Warnings for the locations detailed in Annex C
Action :	1. Advise the <CoucilName > City Council and the <SESLN> CCLEOC of flood warning 2. Provide the <SESReg> SESDHQ with information for inclusion in <SESLN>SES Flood Bulletins on the estimated impacts of flooding at the predicted heights
Activity Name :	Evacuation warning
Functionality :	Evacuation warning
Trigger :	When evacuation is required
Action :	Issuing evacuation warning messages as a template is at Annex E
Activity Name :	Playing SEWS
Functionality :	Playing SEWS
Trigger :	When there are Evacuation Warnings or Special Warnings or Dam-Failure Warnings
Action :	Standard Emergency Warning Signal (SEWS) may be played over radio and television stations to alert communities to Evacuation Warnings, Special Warnings or Dam-Failure Warnings

Activity Name :	Collation and dissemination read information
Functionality :	Collation and dissemination read information
Trigger :	When response operation
Action :	1. Provides road status reports for main roads in the council area to the <SESReg> Road Information Cell DHQRIC) and to the <SESLN> Police Local Area Command Headquarters (PLACHQ) 2. Ensuring that the <SESReg> SES Division Controller is regularly briefed on the progress of operations and on future resource needs
Activity Name :	Traffic control
Functionality :	Traffic control
Trigger :	In the event of major flooding
Action :	Direct the imposition of traffic control measures
Activity Name :	Flood rescue
Functionality :	Flood rescue
Trigger :	When response operation
Action :	1. Controls flood rescues, which are carried out using high clearance vehicles, flood boats and (under some circumstances) helicopters 2. Request additional flood boats and crews through the <SESReg> SESDHQ
Activity Name :	Keep inform essential service
Functionality :	Keep inform essential service
Trigger :	When response operation
Action :	1. Ensuring that the providers of essential services (electricity, water, sewerage, medical and public health) are kept advised of the flood situation 2. Kept to be informed status and ongoing ability from Essential service providers
Activity Name :	Maintain logistic
Functionality :	Maintain logistic
Trigger :	When response operation
Action :	Maintaining a small stock of sandbags and back-up supplies are available through the <SESReg> SESDHQ. A motorised sandbag-filling machine is available from <SESReg> SESDHQ. Alternatively, local concrete trucks may be used
Activity Name :	Managing aircraft
Functionality :	Managing aircraft
Trigger :	Should only be used if other transport means are not available or not suitable
Action :	Task the aircraft allocated by the Division Headquarters for flood operations within the council area
Activity Name :	Resupply
Functionality :	Resupply
Trigger :	When response operation
Action :	Arranging resupply as the details listed in Annex Q
Activity Name :	Assistance of animals
Functionality :	Assistance of animals
Trigger :	When response operation
Action :	1. Refers to the matters relating to the welfare of livestock, companion animals and wildlife (including feeding and rescue) to NSW Department of Primary Industries 2. Requests for emergency supply and/or delivery of fodder to stranded livestock, or for livestock rescue, are to be passed to NSW Department of Primary Industries
Activity Name :	Assist stranded travellers
Functionality :	Assist stranded travellers
Trigger :	When response operation
Action :	Refers the stranded travellers to Department of Community Services for the arrangement of temporary accommodation

	Activity Name : End of response operation **Functionality :** End of response operation **Trigger :** When response operation **Action :** 1. Advising agencies and the community involved in response operation the end of response operation 2. Briefing Recovery Committee (RC) on the situation and any need to issue an 'all clear' for evacuees to return to their homes
Environment Considerations	[E5] **Resources for distribution** [E6] **Appropriate agencies** [E7] **Resources to be deployed** [E8] **Emergency services** [E9] **Essential agencies** [E14] **Warning massage template for evacuation** [E18] **Infrastructure list of possible risk** [E19] **Resupply arrangements**

Agent Type	LO Type
Name	**<AgencyName> LO**
Description	Play role as the <AgencyName> Liaison Officer
References	**R03**
Activity	**Activity Name :** Deploy the resource **Functionality :** Deploy the resource **Trigger :** At the request of the <SESLN> SESLOC **Action :** 1. Deploy the resources of their parent organisations 2. Advise the <SESLN> SESLOC on resource availability for their service 3. Provide communications to their own organisations
Environment Considerations	[E2] **Communications**

7. *Customised scenario model of the SES NSW DISPLAN template*

DM Plan	*Customised scenario model* of the SES NSW DISPLAN template
Country	Australia
Disaster Type	Flood
Phase	Response phase

Scenario	S01			
Name	**Control Flood Operation**			
Goal	**CFO**			
Initiator	<SESLN> SESLOC			
Trigger	For starting the control of flood operation			
Pre-condition	-			
Post-condition	-			
Description	-			
Condition	**Step**	**Activity**	**Role**	**Environment Entity**
		Coordination of other agencies and organizations for flood management tasks	<SESLN> SESLOC	E1

Scenario	S02			
Name	**Maintain Operation Centre**			
Goal	Maintain Operation Centre			
Initiator	SESLC			
Trigger	For starting the control of flood operation			
Pre-condition	-			
Post-condition	-			
Description	-			
Condition	**Step**	**Activity**	**Role**	**Environment Entity**

Sequential	1	Maintains an Operations Centre at <LocalName> address	<SESLN> SESLOC	
	2	Operates after hours duty officer system whenever flood operations are not being conducted	<SESLN> SESLOC	
	3	Request to provide liaison (including a liaison officer where necessary) to the <SESLN> SES Operations Centre	<SESLN> SESLOC	
	4	Provide a liaison officer, where necessary, to the <SESLN> SES Operations Centre	<SESLN> SESLOC, <AgencyName> LO	E1
	5	LO to deploy the resources of their parent organisations at the request of the <SESLN> SES Local Controller	<SESLN> SESLOC, <AgencyName> LO	
	6	LO to advise the <SESLN> SES Local Controller on resource availability for their service	<SESLN> SESLOC, <AgencyName> LO	
	7	LO to provide communications to their own organisations	<SESLN> SESLOC, <AgencyName> LO	E2

Scenario	S03
Name	**Start of Response Operation**
Goal	Start of Response Operation
Initiator	SESLC
Trigger	1. On receipt of a BoM Preliminary Flood Warning, Flood Warning, Flood Watch or Severe Weather Warning for Flash Flooding 2. On receipt of <DamName> dam-failure warnings 3. When other evidence leads to an expectation of flooding within the council area
Pre-condition	-
Post-condition	-
Description	-

Condition	**Step**	**Activity**	**Role**	**Environment Entity**
Sequential	1	Contact with the BoM to discuss the development of flood warnings will normally be through the <SESReg> SESDHQ	<SESLN> SESLOC	
	2	Advising <CouncilName> CCLEOC for flooding anticipated response (for transmission to the <LocalPolice> NSW Police Local Area Command Headquarters	SES NSW	
	3	Request to advise other organizations to initiate response operation (as listed in this DM plan) for flooding anticipation	<SESLN> SESLC, <CouncilName> CCLEMO	E1
	4	Advises other agencies listed in this plan to start the response operation regardless of the location and severity of the flooding to the appropriate location and the nature of the threat.	<SESLN> SESLC, <CouncilName> CCLEMO	E1,E3

Scenario	S04
Name	**Providing Flood Intelligence (FI) Sources**
Goal	Providing Flood Intelligence (FI) Sources
Initiator	BoM
Trigger	Times of flooding
Pre-condition	-
Post-condition	-

Description	-

Condition	Step	Activity	Role	Environment Entity
Sequential	1	Provides Flood Watches, which give an early appreciation of developing meteorological situations that could lead to flooding. These are normally provided on a whole-catchment basis for the <Regional> River catchment	BoM, <SESReg> SESDHQ, <SESLN> SESLC	
	2	Provides Flood Warnings, which include river height readings and height-time predictions. The gauges for which predictions are provided for are listed in Annex C	BoM, <SESReg>SESDHQ, <SESLN> SESLC	E4
	3	Provides Severe Weather Warnings for Flash Flooding	BoM, <SESReg>SESDHQ, <SESLN> SESLC	
	4	Provides Key gauge level information is available from the BoM website, www.bom.gov.au	BoM, <SESReg>SESDHQ, <SESLN> SESLC	
	5	Provides information on flooding and its consequences, including those in nearby council areas	<SESReg> SESDHQ, <SESLN> SESLC	
	6	Advise of road closures within the council area	<CityCouncil> CC	
	7	Provides information Dams and the likely effects of failure	<DamAgency><SESReg> SESDHQ, <SESLN> SESLC	
	10	Advises flow rates and rates of rise for the <Regional> River. Daily river level report are available on-line at http://waterinfo.dlwc.nsw.gov.au/riis/drr/index.html	DoIPaNS, <SESReg> SESDHQ, <SESLN> SESLC	
	11	Active reconnaissance	SES NSW, <SESLN> SESLC	E4

Scenario	S05
Name	**Preliminary Deployment**
Goal	Preliminary Deployment
Initiator	<SESLN> SESLC
Trigger	1. When flooding is expected to be severe enough to cut road access to towns, within towns and/or rural communities 2. When towns and villages are expected to become isolated
Pre-condition	-
Post-condition	-
Description	-

Condition	Step	Activity	Role	Environment Entity
Interleave	1	Ensuring that resources are in place for the distribution of foodstuffs and medical supplies to the areas that could become isolated	SES NSW, <SESLN> SESLC	E5
	2	Advising appropriate agencies so that resources (including sandbags, firefighting appliances, ambulances, etc.) are deployed to ensure that operational capability is maintained. Pre-deployments may be required for up to one week	SES NSW	E6

Scenario	S06
Name	**Protection of Resources**
Goal	Protection of Resources
Initiator	<SESLN> SESLC
Trigger	When the <CityCouncil> levee is predicted to overtop or fail

Pre-condition	-
Post-condition	-
Description	-

Condition	Step	Activity	Role	Environment Entity
		Advising emergency services and essential agencies located on the floodplain to relocate resources to flood free locations	SES NSW, <SESLN> SESLC	E8,E9

Scenario	S07
Name	**Arrange Warning Service Operations**
Goal	Arrange Warning Service Operations
Initiator	SESLHQ
Trigger	-
Pre-condition	
Post-condition	-
Description	-

Condition	Step	Activity	Role	Environment Entity
Sequential	1	Advices to the Murrumbidgee SES Division Headquarters on current and expected impacts of flooding	<SESLN> SESLHQ, <SESReg> SESDHQ	
	2	Coordinates the delivery of warnings to the community by doorknocking, telephone, mobile public address systems, local radio stations and two-way radio	<SESLN> SESLHQ	
	3	Confirmation of evacuation actions	<SESLN> SESLHQ	
	4	The MSESDHQ issues warning information in the form of SES Division Flood Bulletins to media organisations and agencies listed in Annex D.	<SESLN> SESLC, <SESReg> SESDHQ	E10
	5	Advises the MSESDHQ which will issue SES Livestock and Equipment Warnings to radio stations as indicated in Annex D	<SESLN> SESLC, <SESReg> SESDHQ	E10
	6	Issues SES Livestock and Equipment Warnings to radio stations as indicated in Annex D	<SESLN> SESLC, <SESReg> SESDHQ	E10
	7	Maintains a list of landholders along the Murrumbidgee River and its tributaries	<SESLN> SESLC, <SESReg> SESDHQ	E11

Scenario	S08
Name	**Release BoM Flood Watches**
Goal	Release BoM Flood Watches
Initiator	<SESReg> SESDHQ
Trigger	If there are signs of impending floods
Pre-condition	
Post-condition	-
Description	-

Condition	Step	Activity	Role	Environment Entity
Sequential	1	Releases BoM Flood Watches to radio stations which will be incorporated in <SESLN> SES Flood Bulletins	<SESReg> SESDHQ, <SESLN> SESLC	E12
	2	Issues BoM Flood Warnings as detailed in Annex C	<SESReg> SESDHQ	

	3	Advise the <CouncilName> CC and the <CouncilName> CCLEOC Controller of impending flooding	<SESLN> SESLC, <CityCouncil> CC, <CituCounil> CCLEOC	
	4	Provide the <SESReg> SESDHQ with information for inclusion in SES Flood Bulletins on the estimated impacts of flooding at the predicted heights	<SESReg> SESDHQ	E17

Scenario	S09
Name	**Provides BoM Severe Weather Warnings for Flash Flooding**
Goal	Provides BoM Severe Weather Warnings for Flash Flooding
Initiator	<SESReg> SESDHQ
Trigger	An intense rainfall
Pre-condition	when severe weather is expected to affect land based communities with 6 to 24 Hours
Post-condition	-
Description	-

Condition	**Step**	**Activity**	**Role**	**Environment Entity**
Sequential	1	Provides a warning of the possibility for BoM Severe Weather Warnings for Flash Flooding as a result of intense rainfall.	<SESReg> SESDHQ, <SESLN> SESLC	E13
	2	Issues Local Flood Advices for the gauges listed in Annex C. These are issued in SES Division Flood Bulletins and/or direct from the <SESLN> SES Local Controller via facsimile.	<SESReg> SESDHQ, <SESLN> SESLC	E17

Scenario	S10
Name	**Issues Evacuation Warning**
Goal	Issues Evacuation Warning
Initiator	<SESLN> SESLC
Trigger	When evacuation is required
Pre-condition	in the case of severe flooding that may have the potential to cause the failure of <DamName> Dam
Post-condition	-
Description	-

Condition	**Step**	**Activity**	**Role**	**Environment Entity**
Interleave	1	Issues Evacuation Warning	<SESReg> SESDHQ, <SESLN> SESLC	E14
	2	Issues Dam failure warnings to media outlets by the MSESDHQ. Details of these arrangements are described in Annex I	<SESReg> SESDHQ, <SESLN> SESLC	E15
	3	Standard Emergency Warning Signal (SEWS) may be played over radio and television stations to alert communities to Evacuation Warnings, Special Warnings or Dam-Failure Warnings	<SESLN> SESLC, <SESLN> SESLHQ, <SESReg> SESDHQ	

Scenario	S11
Name	**Issues Flood Information on behalf SES units**
Goal	Issues Flood Information on behalf SES units
Initiator	SESLC
Trigger	When evacuation is required
Pre-condition	in the case of severe flooding that may have the potential to cause the failure of Burrinjuck, Talbingo and Blowering Dam
Post-condition	-
Description	-

Condition	**Step**	**Activity**	**Role**	**Environment Entity**
Sequential	1	Maintains pre-written flood bulletins for key heights	<SESReg> SESDHQ	E10,E17

	2	Provides a 'phone-in' information service for the community in relation to current warnings, river heights, flood behaviour, road conditions and closures of local and main roads	<SESReg> SESDHQ	
	3	Provides advice on safety matters and means of protecting property	<SESReg> SESDHQ	E10
	4	Provides road status reports for main roads in the council area to the <SESReg> SESDHQRIC and to the <LocalPolice> PLACHQ	<SESReg> SESDHQ, <LocalPolice> Police LACHQ	
	5	Distributes information on main roads to <SESLN> SES units, media outlets and agencies as part of <SESLN> SES Flood Bulletins		E10
	6	RIC (<SESReg> SESDHQRIC) also provides a 'phone-in' service to the public		
	7	Ensures that the <SESReg> SESDHQ is regularly briefed on the progress of operations and on future resource needs		

Scenario	S12
Name	**Road Control**
Goal	Road Control
Initiator	<SESLN> SESLC
Trigger	When evacuation is required
Pre-condition	in the case of severe flooding that may have the potential to cause the failure of <DamName> Dam
Post-condition	-
Description	-

Condition	**Step**	**Activity**	**Role**	**Environment Entity**
Interleave	1	Closes and re-opens its own roads	<CouncilName>CC	E14
	2	close and re-open roads but will normally only do so (if the council or the RTA have not already acted) if public safety requires such action	<LocalPolice> Police NSW, RTA	

Scenario	S13
Name	**Traffic Control**
Goal	Traffic Control
Initiator	<SESLN> SESLC
Trigger	In the event of major flooding
Pre-condition	in the case of severe flooding that may have the potential to cause the failure of <DamName> Dam
Post-condition	-
Description	-

Condition	**Step**	**Activity**	**Role**	**Environment Entity**
Sequential	1	Direct the imposition of traffic control measures	<SESLN> SESLC	
	2	Provided assistance to <SESLN> SESLC in the erection of barricades and signs	<COuncilName> CC, <SESLN> SESLOC	
	3	Controls flood rescues, which are carried out using high clearance vehicles, flood boats and (under some circumstances) helicopters	<SESLN> SESLC	
	4	Request additional flood boats and crews through the <SESReg>	<CouncilName> CC, <SESLN> SESLC	

	5	Arranging evacuation for the <CouncilName> City Council area as listed in Annexes F to O		
	6	Ensures that the providers of essential services are kept advised of the flood situation. The detail of essential services as listed in Annex B		
	7	Essential service providers must keep the <SESLN> SES Local Controller abreast of their status and ongoing ability to provide those services.	SESLC	E18
	8	Maintains a small stock of sandbags, and back-up supplies are available through the <SESReg> SESDHQ. A motorised sandbag-filling machine is available from <SESReg> SESDHQ	SESLHQ, MSESDHQ	

Scenario	S14
Name	**Managing aircraft**
Goal	Managing aircraft
Initiator	<SESLN> SESLC
Trigger	Should only be used if other transport means are not available or not suitable
Pre-condition	
Post-condition	-
Description	-

Condition	**Step**	**Activity**	**Role**	**Environment Entity**
Sequential	1	Control air support operations	<SESReg> SESDHQ, <SESLN> SESLC	
	2	Tasks aircraft allocated by the Division Headquarters for flood operations within the council area	<SESReg> SESDHQ, <SESLN> SESLC	

Scenario	S15
Name	**Resupply operation**
Goal	Resupply operation
Initiator	<SESLN> SESLC
Trigger	During periods of flooding many rural properties and some villages can become isolated
Pre-condition	-
Post-condition	-
Description	-

Condition	**Step**	**Activity**	**Role**	**Environment Entity**
Sequential		Resupply arrangements are detailed in Annex Q	<SESLN> SESLC	

Scenario	S18
Name	**End of Response Operation**
Goal	End of Response Operation
Initiator	<SESLN> SESLC
Trigger	When response operations have concluded
Pre-condition	-
Post-condition	-
Description	-

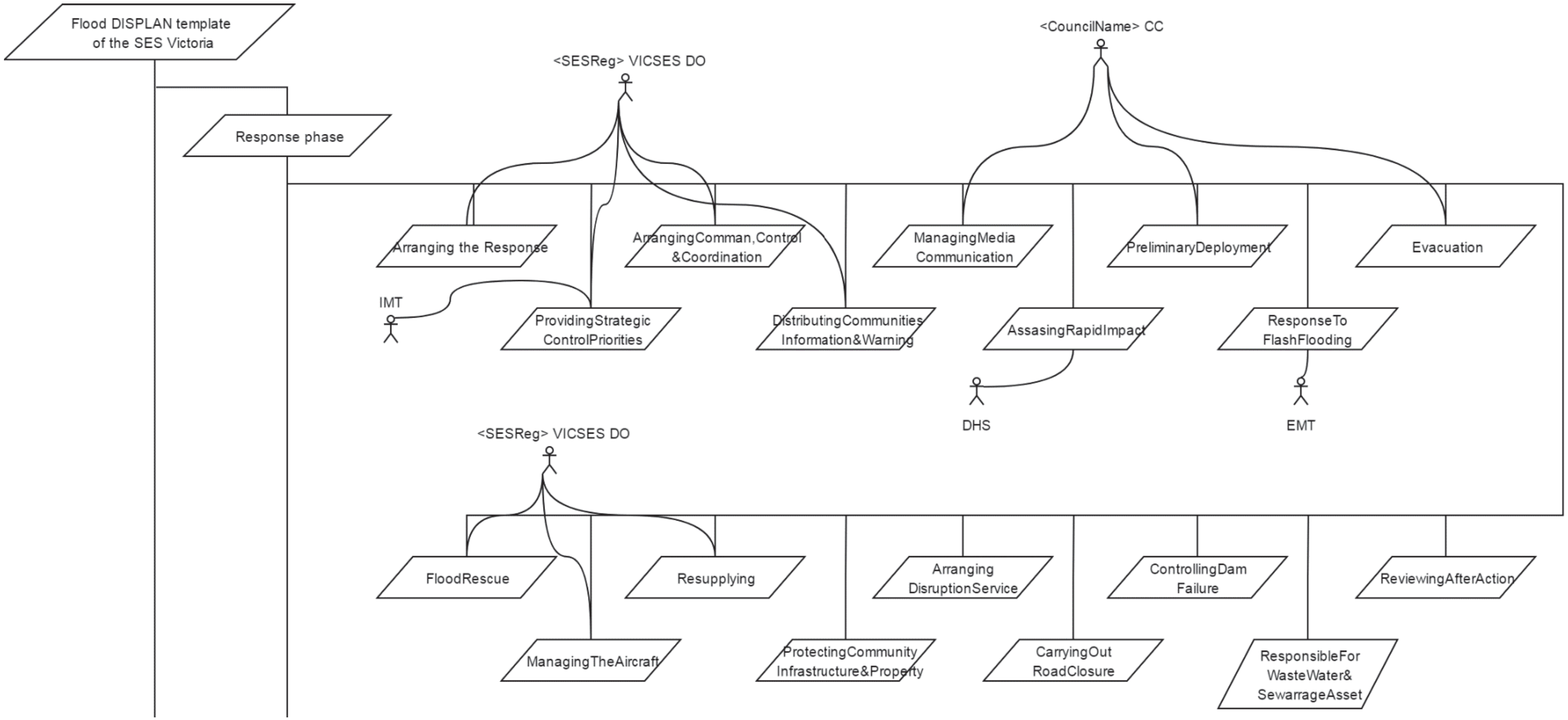
Condition	**Step**	**Activity**	**Role**	**Environment Entity**
Sequential	1	Advises other agencies and the community of the end of response operation	<SESLN> SESLC, DoPI	
	2	The recovery committee if established will be briefed on the situation and any need to issue an 'all clear' for evacuees to return to their homes.	<SESLN> SESLC, RC	

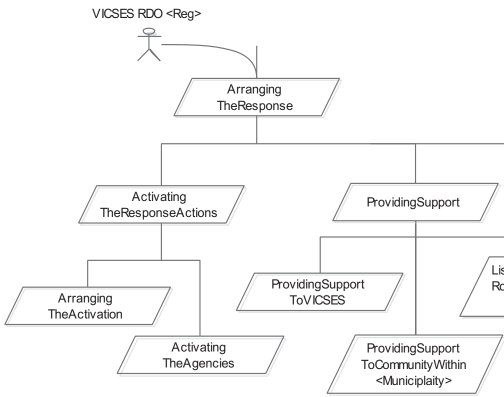
Appendix E

Customised ABMs of flood DISPLAN of the SES Victoria

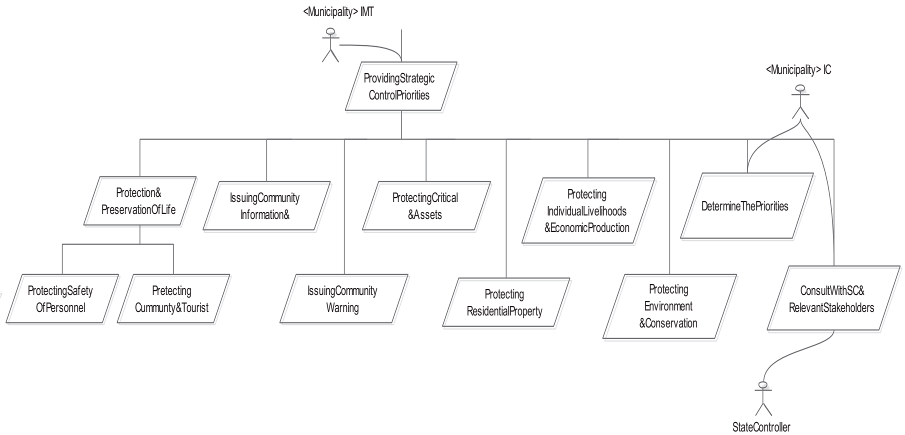
DISPLAN	Customised *goal model* of the SES Victoria DISPLAN template
Country	Australia
Disaster Type	Flood
Phase	Response phase

1. *Customised goal model of flood DISPLAN of the SES Victoria*

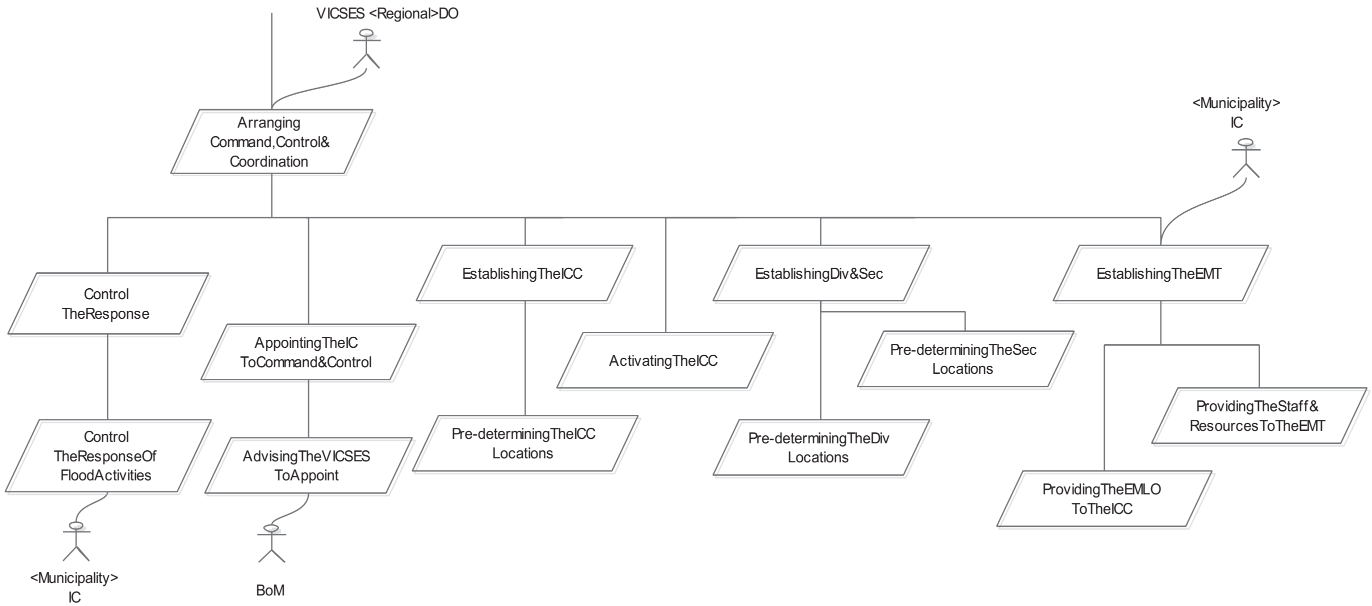




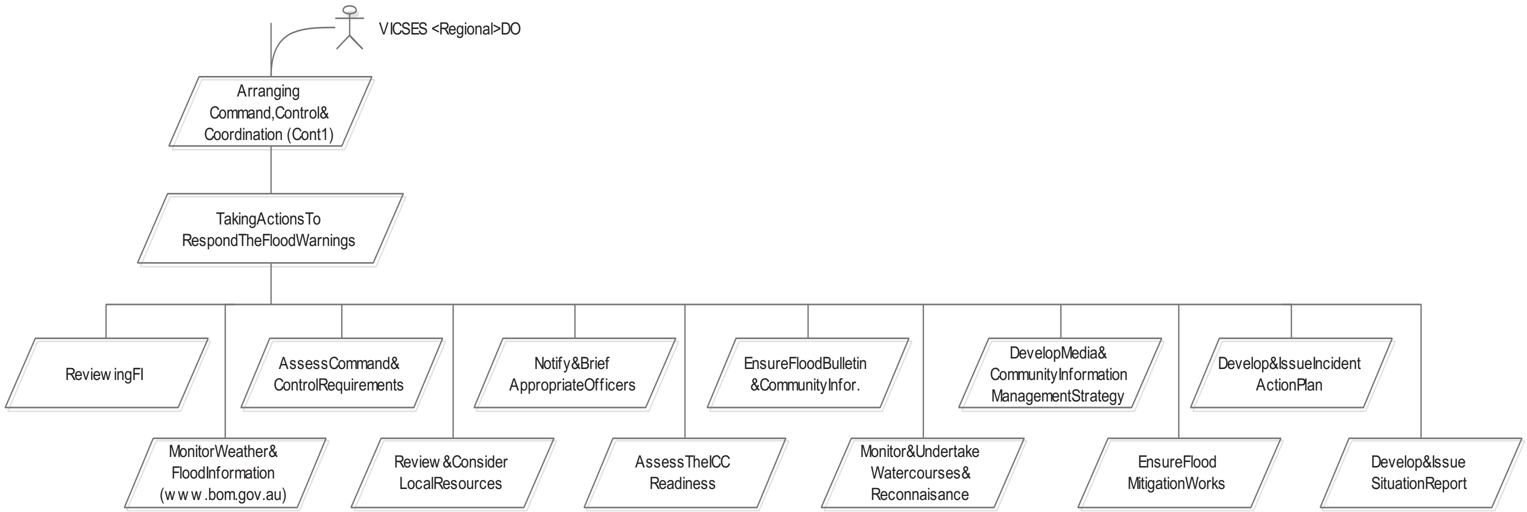
VICSES RDO <Reg>
Arranging TheResponse
Activating TheResponseActions
ProvidingSupport
Establishing The<Municipality>ECC
Arranging TheActivation
Activating TheAgencies
ProvidingSupport ToVICSES
ListingAllTheAgreed RolesOfTheInvolved Agencies
ProvidingSupport ToCommunityWithin <Municiplaity>
Coordinating TheEscalationOf FloodIncident

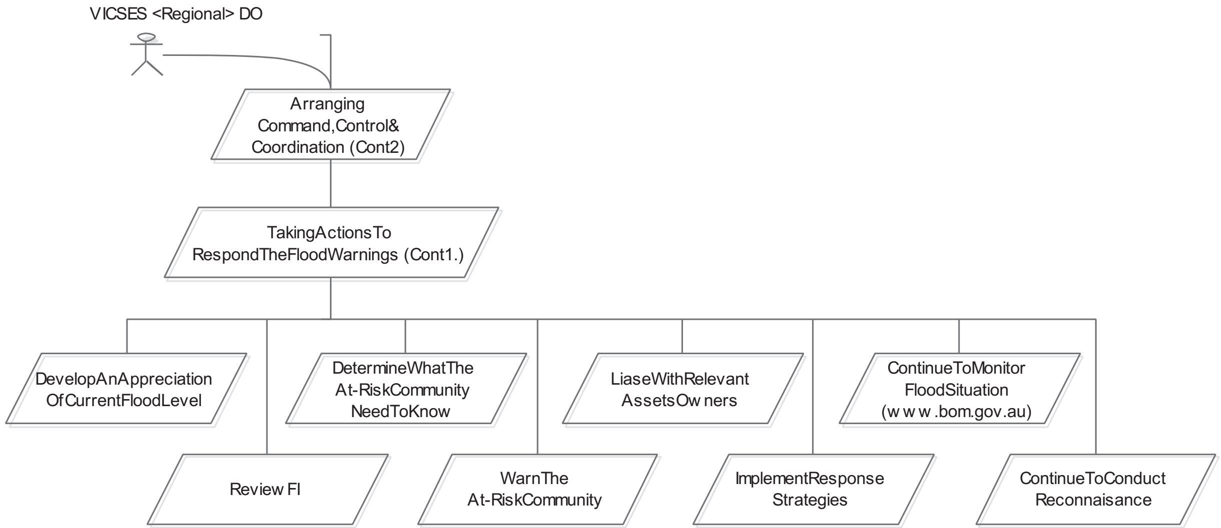


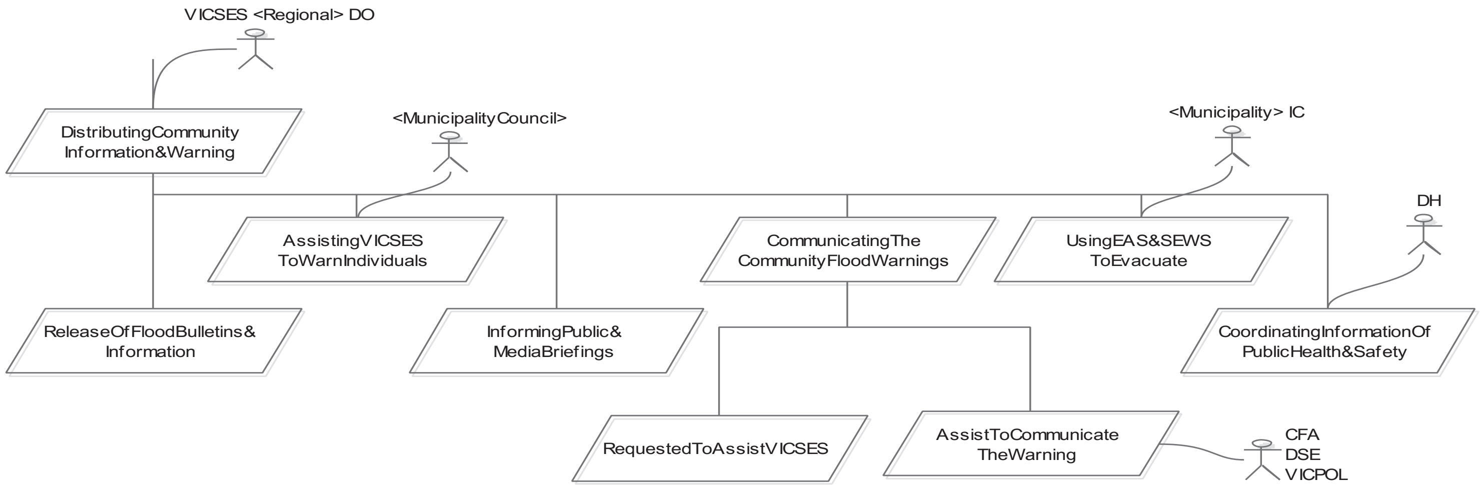
<Municipality> IMT
ProvidingStrategic ControlPriorities
<Municipality> IC
Protection& PreservationOfLife
IssuingCommunity Information&
ProtectingCritical &Assets
Protecting IndividualLivelihoods &EconomicProduction
DetermineThePriorities
ProtectingSafety OfPersonnel
Pretecting Cummunty&Tourist
IssuingCommunity Warning
Protecting ResidentialProperty
Protecting Environment &Conservation
ConsultWithSC& RelevantStakeholders
StateController



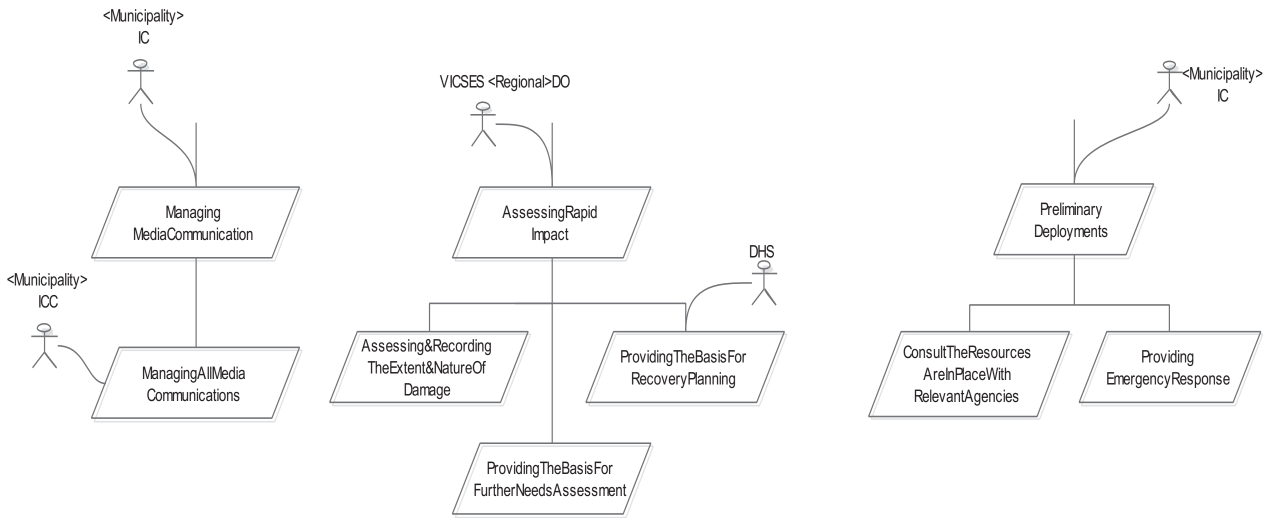
VICSES <Regional>DO
Arranging Command,Control& Coordination
<Municipality> IC
Control TheResponse
AppointingTheIC ToCommand&Control
EstablishingTheICC
ActivatingTheICC
EstablishingDiv&Sec
Pre-determiningTheSec Locations
EstablishingTheEMT
ProvidingTheStaff& ResourcesToTheEMT
Control TheResponseOf FloodActivities
AdvisingTheVICSES ToAppoint
Pre-determiningTheICC Locations
Pre-determiningTheDiv Locations
ProvidingTheEMLO ToTheICC
<Municipality> IC
BoM

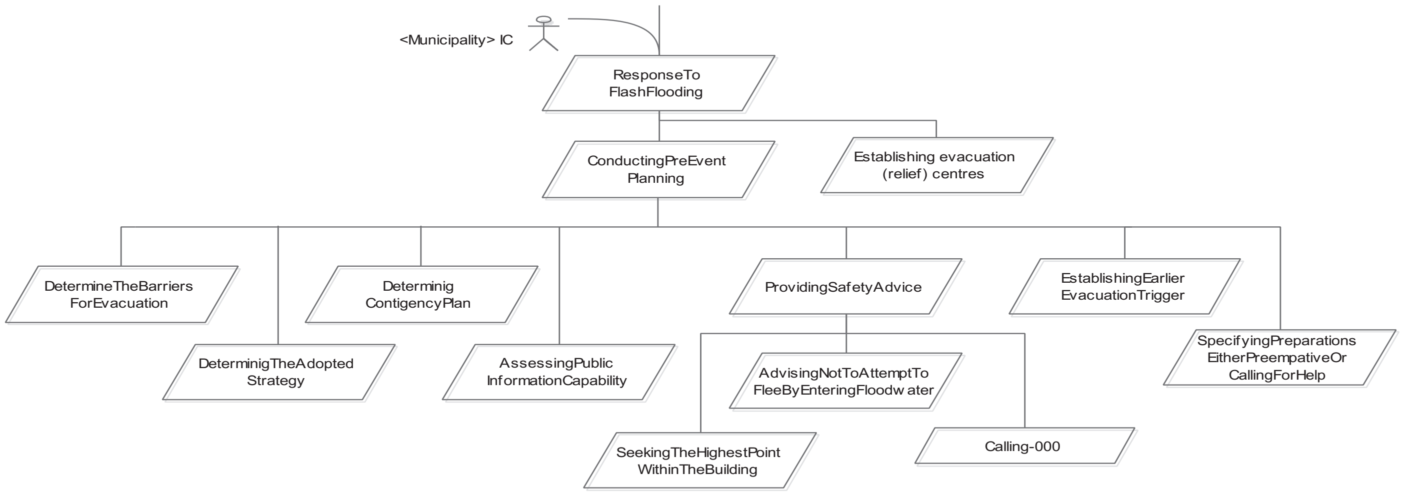

VICSES <Regional>DO
Arranging Command,Control& Coordination (Cont1)
TakingActionsTo RespondTheFloodWarnings
Review ingFI
AssessCommand& ControlRequirements
Notify&Brief AppropriateOfficers
EnsureFloodBulletin &CommunityInfor.
DevelopMedia& CommunityInformation ManagementStrategy
Develop&IssueIncident ActionPlan
MonitorWeather& FloodInformation (w w w .bom.gov.au)
Review &Consider LocalResources
AssessTheICC Readiness
Monitor&Undertake Watercourses& Reconnaisance
EnsureFlood MitigationWorks
Develop&Issue SituationReport

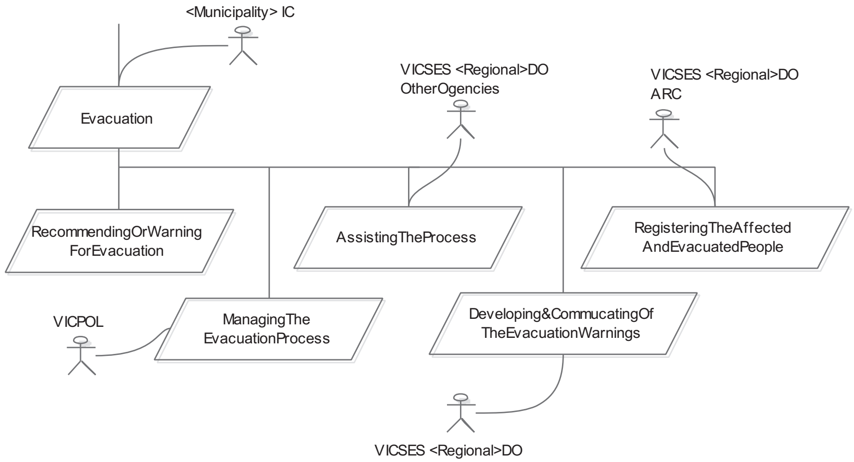

VICSES <Regional> DO
Arranging Command,Control& Coordination (Cont2)
TakingActionsTo RespondTheFloodWarnings (Cont1.)
DevelopAnAppreciation OfCurrentFloodLevel
DetermineWhatThe At-RiskCommunity NeedToKnow
LiaseWithRelevant AssetsOw ners
ContinueToMonitor FloodSituation (w w w .bom.gov.au)
Review FI
WarnThe At-RiskCommunity
ImplementResponse Strategies
ContinueToConduct Reconnaisance

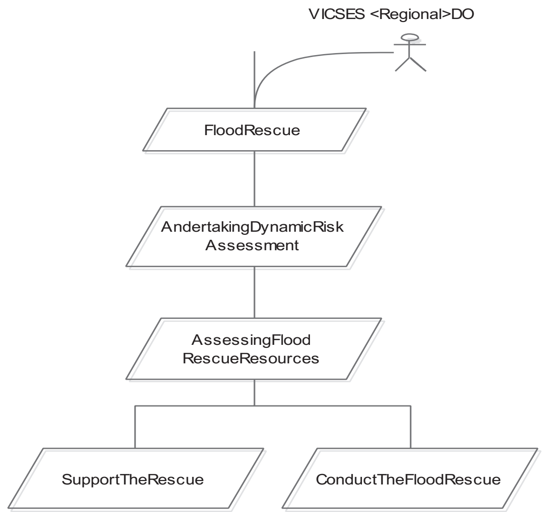


EAS = Emergency Alert System
SEWS = Standard Emergency Warning System
DH = Department of Health

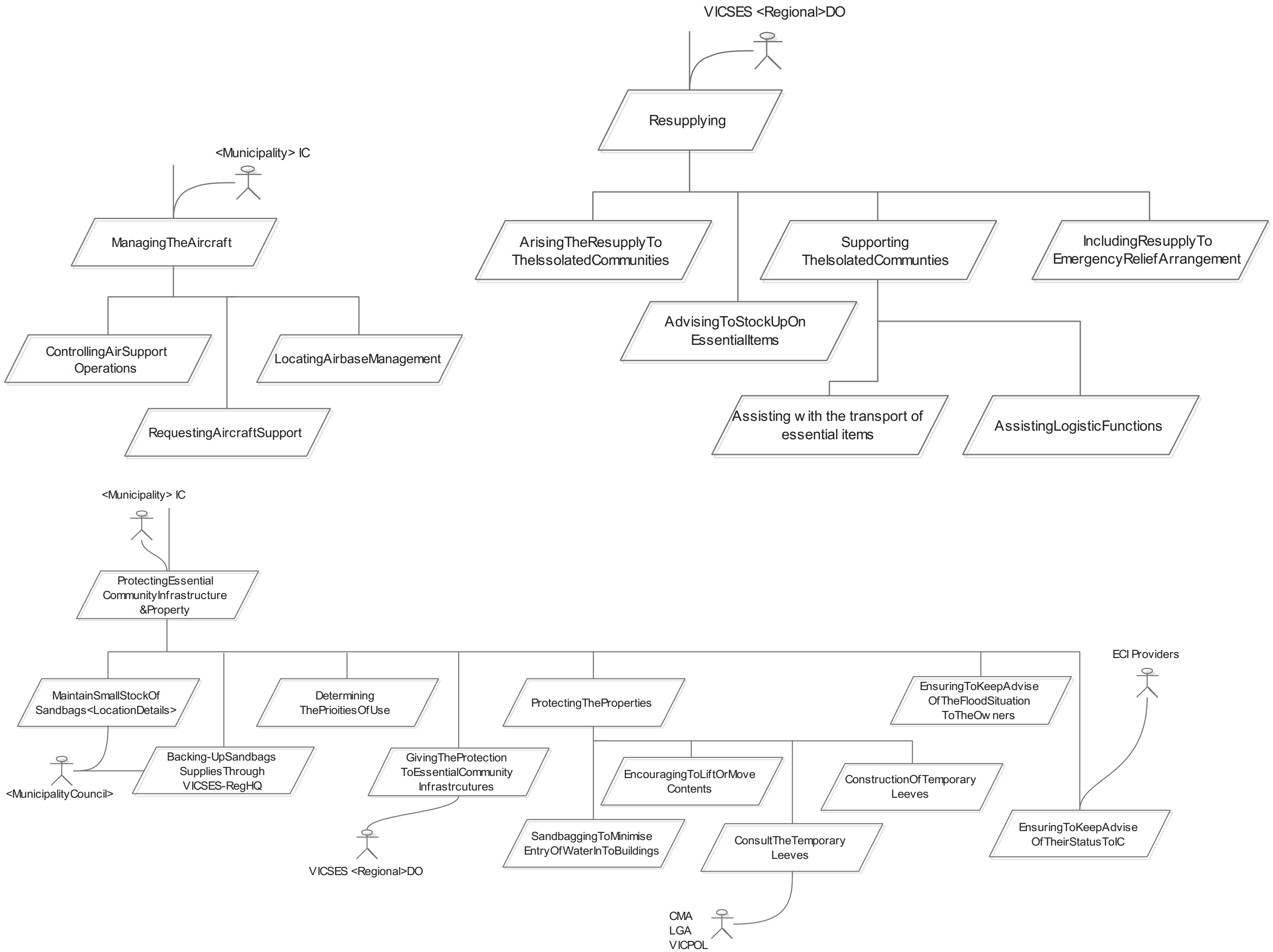


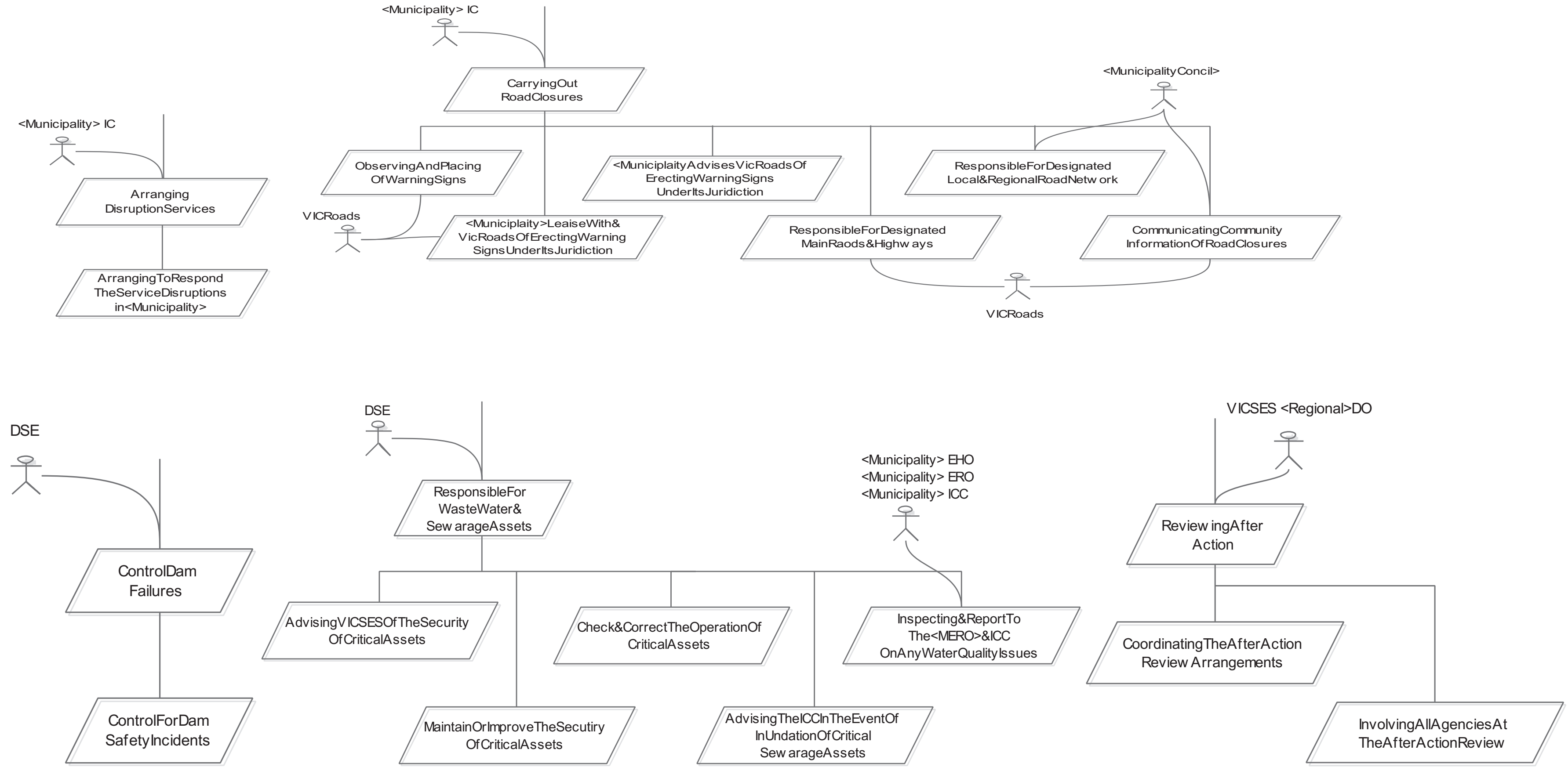






ARC = Australian Red Cross


VICSES <Regional>DO
Resupplying
ArisingTheResupplyTo TheIssolatedCommunities
AdvisingToStockUpOn EssentialItems
Supporting TheIsolatedCommunties
IncludingResupplyTo EmergencyReliefArrangement
Assisting w ith the transport of essential items
AssistingLogisticFunctions
<Municipality> IC
ManagingTheAircraft
ControllingAirSupport Operations
LocatingAirbaseManagement
RequestingAircraftSupport
<Municipality> IC
ProtectingEssential CommunityInfrastructure &Property
MaintainSmallStockOf Sandbags<LocationDetails>
<MunicipalityCouncil>
Backing-UpSandbags SuppliesThrough VICSES-RegHQ
Determining ThePrioitiesOfUse
GivingTheProtection ToEssentialCommunity Infrastrcutures
VICSES <Regional>DO
ProtectingTheProperties
EncouragingToLiftOrMove Contents
ConstructionOfTemporary Leeves
SandbaggingToMinimise EntryOfWaterInToBuildings
ConsultTheTemporary Leeves
CMA
LGA
VICPOL
EnsuringToKeepAdvise OfTheFloodSituation ToTheOw ners
ECI Providers
EnsuringToKeepAdvise OfTheirStatusToIC



DSE = Department of Sustainability Environment
MERO = <Municipality> Emergency Resource Officer
MEHO = <Municipality> Emergency Health Officer

DISPLAN	Customised *role model* of the SES Victoria DISPLAN template
Country	Australia
Disaster Type	Flood
Phase	Response phase

2. *Customised role model of flood DISPLAN of the SES Victoria*

Role ID	R1
Name	**VIC SES <Regional> DO**
Description	Victoria State Emergency Service <Regional> Duty Officer. <Regional> will be substituted with the appropriate region.
Responsibilities	1. Arranging the response 2. Activating the response actions 3. Arranging the activation 4. Activating the agencies 5. Providing support 6. Providing support to VIC SES 7. Providing support to community within <Municipality> 8. Listing all the agreed roles of the involved agencies 9. Establishing the <Municipality> Emergency Coordination Centre (MECC) 10. Coordinating the escalation of flood incident 11. Arranging Command, Control & Coordination 12. Controlling the response 13. Controlling the response of the flood activities 14. Appointing the IC to command and controller 15. Advising the VICSES to appoint the <Municipality> IC 16. Establishing an <Municipality> Incident Control Centre (ICC) 17. Pre-determining Incident Control Centre locations 18. Activating the <Municipality> ICC 19. Establishing Divisions and Sectors 20. Pre-determining divisions locations 21. Pre-determining sectors locations 22. Establishing the EMT 23. Providing an Emergency Management Liaison Officer (EMLO) to the EMT 24. Providing other staffs and / or resources to the EMT 25. Taking actions to response the flood warnings 26. Reviewing flood information 27. Monitoring weather and flood information - www.bom.gov.au 28. Assessing Command and Control requirements 29. Review and consider local resources 30. Notify and brief appropriate officers 31. Assessing ICC readiness 32. Ensure flood bulletins and community information 33. Monitor and undertake watercourses reconnaissance 34. Develop media and community information management strategy 35. Ensure flood mitigation are being checked 36. Develop and issue incident action plan 37. Develop and issue situation report 38. Develop an appreciation of current flood and predicted levels 39. Review flood intelligence 40. Determining what the at-risk community need to know 41. Warning the at-risk community including 42. Liaising with relevant asset owners 43. Implementing response strategies 44. Continuing to monitor the flood situation – www.bom.gov.au/vic/flood/ 45. Continuing to conduct reconnaissance 46. Distributing of community information and warnings 47. Releasing of flood bulletins and information 48. Assisting the VICSES to warn individuals within the community 49. Informing public and media briefing 50. Communicating of community flood warnings 51. Requesting to assist VICSES 52. Assisting to communicate warnings 53. Using the EAS and SEWS to evacuate

	54. Coordinating the information of public health and safety precautions 55. Assessing a rapid impact 56. Assessing and record the extent and nature of damage 57. Providing the basis for further needs assessment 58. Providing the basis for a recovery planning 59. Assisting the evacuation process 60. Developing and communicating the evacuation warnings 61. Registering people affected by a flood 62. Flood Rescue 63. Undertaking a dynamic risk assessment 64. Assessing of the availability flood rescue resources 65. Support the flood rescue 66. Conduct the flood rescue 67. Resupplying 68. Arising to resupply isolated communities 69. Advising to stocking up on essential items 70. Supporting the isolated communities 71. Assisting with the transport of essential items 72. Assisting with the logistic function 73. Including the resupply to the emergency relief arrangements 74. Giving protection of Essential Community Infrastructure 75. Reviewing after action 76. Coordinating the after action review arrangements 77. Representing at the after action review
Constraints	Functions 5(a) and 5(c) at Part 2 of the Victoria State Emergency Service Act 1986 (as amended)

Role ID	R2
Name	**<Municipality> IMT**
Description	<Municipality> Incident Management Team
Responsibilities	1. Providing strategic control priorities 2. Protection and preservation of life 3. Protection safety personal 4. Protection community and tourist 5. Issuing of community information 6. Issuing of community warnings 7. Protection of critical infrastructure and community assets 8. Protection of residential property 9. Protection of individual livelihoods and economic production 10. Protection of environmental and conservation 11. Determining the priorities 12. Consult with SC and relevant stakeholders
Constraints	The general roles and responsibilities of supporting agencies are as agreed within the <Municipality> EMP, EMMV (Part 7 'Emergency Management Agency Roles') , State Flood Emergency Plan and Regional Flood Emergency Plan

Role ID	R3
Name	**<Municipality> IC**
Description	<Municipality> Incident Controller
Responsibilities	1. Determining the priorities 2. Consult with SC and relevant stakeholders 3. Controlling the response of the flood activities 4. Establishing the IMT 5. Providing an Emergency Management Liaison Officer (EMLO) 6. Providing other staffs and / or resources to the EMT 7. Assisting the VICSES to warn individuals within the community 8. Using the EAS and SEWS to evacuate 9. Managing media communication 10. Manage all Media communications 11. Preliminary Deployments 12. Consulting to ensure that resources are in place 13. Providing emergency response 14. Response to Flash Flooding 15. Conducting pre-event planning

	16. Determining barriers to evacuation 17. Determining adopted strategy 18. Determining contingency plan 19. Assessing public information capability 20. Providing safety advice 21. Advising to seek the highest point 22. Advising them not to attempt to flee by entering floodwater 23. Calling 000 24. Establishing earlier evacuation trigger 25. Making specific preparations 26. Establishing evacuation (relief) centres 27. Evacuation 28. Recommending or warning people to evacuate immediately 29. Management of the evacuation process 30. Assisting the evacuation process 31. Developing and communicating the evacuation warnings 32. Registering people affected by a flood 33. Managing the aircraft 34. Controlling air support operation 35. Requesting air support operation 36. Locating air base management 37. Protecting essential Community Infrastructure and Property 38. Maintaining a small stock of sandbags 39. Backing up supplies 40. Determining the priorities related the use of sandbags 41. Giving protection of Essential Community Infrastructure 42. Protecting the priorities 43. Sandbagging to minimise entry of water 44. Encouraging businesses and households 45. Consulting of temporary levees 46. Construction of temporary levees 47. Ensuring to keep advised of the flood situation 48. Keeping to inform the status to Incident Controller 49. Arranging disruption services 50. Arranging to respond the service disruption in <Municipality > 51. Carrying out road closures 52. Observing and placing of warning signs 53. Liaising with VicRoads of erecting warning signs, closing roads and bridges 54. Advising the VicRoads of erecting warning signs, of closing roads and bridges 55. Designating main roads and highways 56. Designating local and regional road network 57. Communicating information regarding road closures
Constraints	The general roles and responsibilities of supporting agencies are as agreed within the <Municipality> EMP, EMMV (Part 7 'Emergency Management Agency Roles') , State Flood Emergency Plan and Regional Flood Emergency Plan

Role ID	R4
Name	**StateController**
Description	State Controller – Controller at state level
Responsibilities	1. Consult with SC and relevant stakeholders
Constraints	-

Role ID	R5
Name	**BoM**
Description	Bureau of Meteorology at state level
Responsibilities	1. Advising the VICSES to appoint the <Municipality> IC
Constraints	-

Role ID	R6
Name	**<MunicipalityCouncil>**
Description	<MunicipalityCouncil> - Substituted with the Council's name where this plan will be implemented

Responsibilities	1. Assisting the VICSES to warn individuals within the community 2. Maintaining a small stock of sandbags 3. Backing up supplies 4. Designating local and regional road network 5. Communicating information regarding road closures
Constraints	The general roles and responsibilities of supporting agencies are as agreed within the <Municipality> EMP, EMMV (Part 7 'Emergency Management Agency Roles') , State Flood Emergency Plan and Regional Flood Emergency Plan

Role ID	R7
Name	**DH**
Description	Department of Health – at state level
Responsibilities	1. Coordinating the information of public health and safety precautions
Constraints	-

Role ID	R8
Name	**CFA**
Description	Country Fire Authority – at state level
Responsibilities	1. Assisting to communicate warnings
Constraints	-

Role ID	R9
Name	**DSE**
Description	Department of Sustainability and Environment (successor body to DNRE)
Responsibilities	1. Assisting to communicate warnings 2. Controlling DAM failures 3. Controlling for DAM safety incidents 4. Responsible Waste Water and Critical Sewerage Assets 5. Advising VICSES of the security of critical sewerage assets 6. Maintaining or improving the security 7. Checking and correcting the operation of critical sewerage assets 8. Advising the ICC 9. Inspecting and reporting on any water quality issues
Constraints	-

Role ID	R10
Name	**VICPOL**
Description	Victoria Police
Responsibilities	1. Assisting to communicate warnings 2. Consulting of temporary levees 3. Managing the evacuation process
Constraints	-

Role ID	R11
Name	**<Municipality> ICC**
Description	<Municipality> Incident Controller Centre
Responsibilities	1. Managing all Media communications 2. Inspecting and reporting on any water quality issues
Constraints	The general roles and responsibilities of supporting agencies are as agreed within the <Municipality> EMP, EMMV (Part 7 'Emergency Management Agency Roles') , State Flood Emergency Plan and Regional Flood Emergency Plan

Role ID	R12
Name	**DHS**
Description	Department of Human Services
Responsibilities	1. Providing the basis for a recovery planning
Constraints	-

Role ID	R13
Name	**ARC**
Description	Australia Red Cross
Responsibilities	1. Registering people affected by a flood
Constraints	-

Role ID	R14
Name	**CMA**
Description	Catchment Management Authority
Responsibilities	1. Consulting of temporary levees
Constraints	-

Role ID	R15
Name	**LGA**
Description	Local Government Association
Responsibilities	1. Consulting of temporary levees
Constraints	-

Role ID	R16
Name	**ECI Providers**
Description	Essential Community Infrastructure Providers
Responsibilities	1. Keeping to inform the status to Incident Controller
Constraints	-

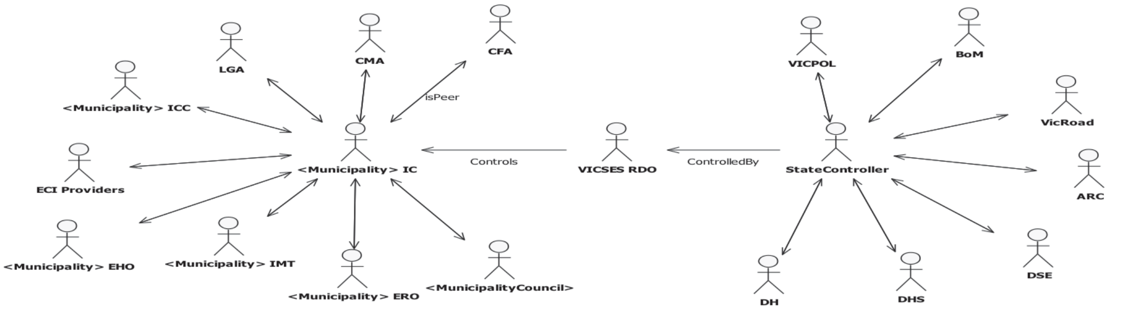
Role ID	R17
Name	**VicRoad**
Description	Victoria Road Authority
Responsibilities	1. Observing and placing of warning signs 2. Liaising with VicRoads of erecting warning signs, closing roads and bridges 3. Designating main roads and highways 4. Communicating information regarding road closures
Constraints	-

Role ID	R18
Name	**<Municipality> EHO**
Description	<Municipality> Emergency Health Officer
Responsibilities	1. Inspecting and reporting on any water quality issues
Constraints	The general roles and responsibilities of supporting agencies are as agreed within the <Municipality> EMP, EMMV (Part 7 'Emergency Management Agency Roles') , State Flood Emergency Plan and Regional Flood Emergency Plan

Role ID	R19
Name	**<Municipality> ERO**
Description	<Municipality> Emergency Resource Officer
Responsibilities	1. Inspecting and reporting on any water quality issues
Constraints	The general roles and responsibilities of supporting agencies are as agreed within the <Municipality> EMP, EMMV (Part 7 'Emergency Management Agency Roles') , State Flood Emergency Plan and Regional Flood Emergency Plan

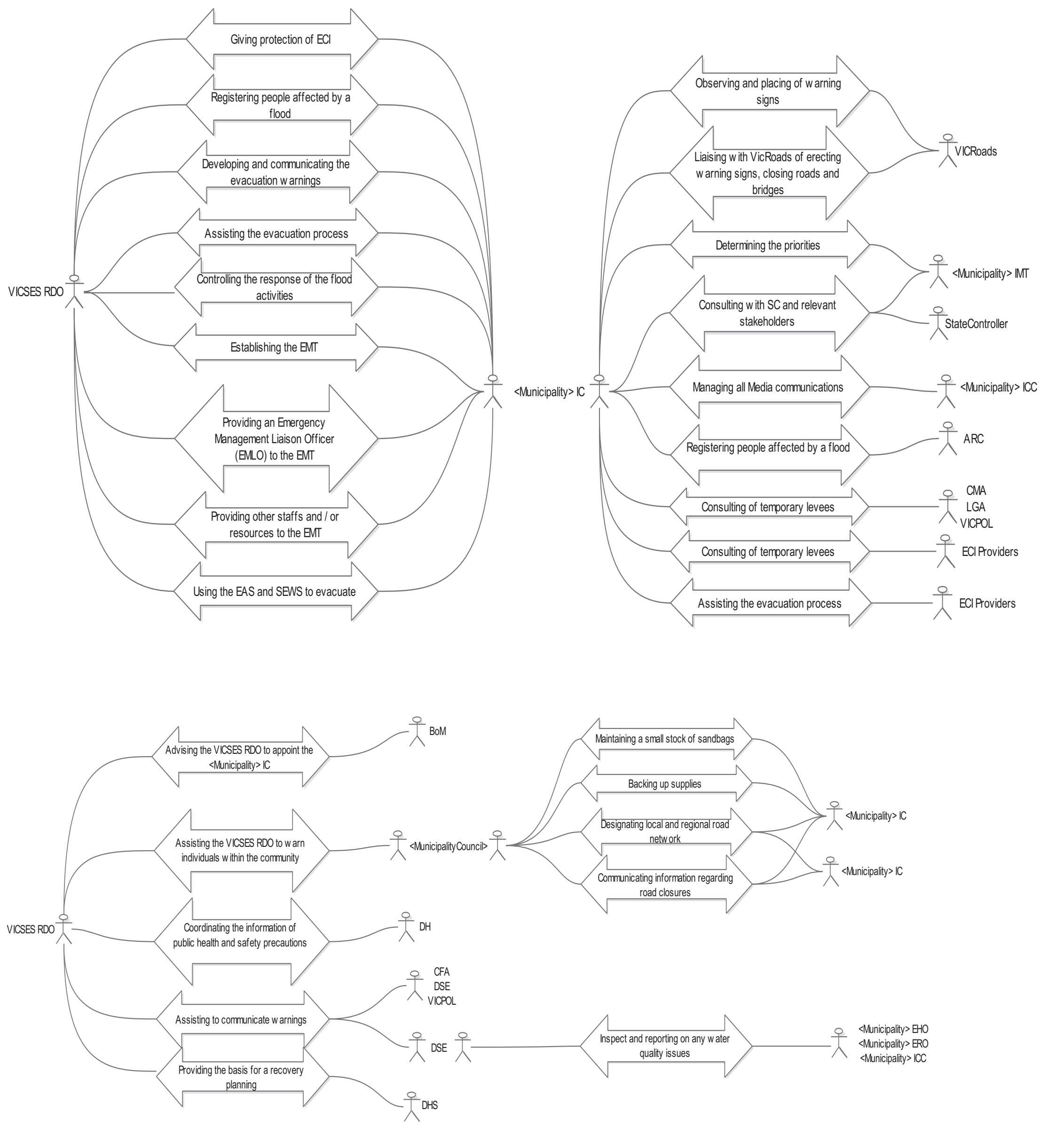
DISPLAN	Customised *organisation model* of the SES Victoria DISPLAN template
Country	Australia
Disaster Type	Flood
Phase	Response phase

3. *Customised organisation model of flood DISPLAN of the SES Victoria*



DISPLAN	Customised *interaction model* of the SES Victoria DISPLAN template
Country	Australia
Disaster Type	Flood
Phase	Response phase

4. *Customised interaction model of flood DISPLAN of the SES Victoria*



DISPLAN	Customised *environment model* of the SES Victoria DISPLAN template
Country	Australia
Disaster Type	Flood
Phase	Response phase

5. *Customised environment model of flood DISPLAN of the SES Victoria*

E1	**List of involved agencies**	
Name	List of involved agencies	
Environment Entity ID	E1	
Description	There are a number of agencies with specific roles that will act in support of VICSES and provide support to the community in the event of a serious flood within the [Enter Municipality Name]	
Attributes	Name	Name of organizations/agencies/individual
	Level of jurisdiction	Level of jurisdiction
	Contact number	Contact number of it
	Contact person	Person can be contacted
Roles Involved	VIC SES <Regional> DO	
	<Municipality> IMT	
	<Municipality> IC	
	StateController	
	BoM	
	<MunicipalityCouncil>	
	DH	
	CFA	
	DSE	
	VICPOL	
	<Municipality> ICC	
	DHS	
	ARC	
	CMA	
	LGA	
	ECI Providers	
	VicRoad	
	<Municipality> EHO	
	<Municipality> ERO	

E2	**Community information and community warnings**	
Name	Community information and community warnings	
Environment Entity ID	E2	
Description	Community information and community warnings detailing incident information that is timely, relevant and tailored to assist community members make informed decisions about their safety.	
Attribute	Type of warning	Type of warning
	Time to issue	Time to issue
Roles Involved	<Municipality> IMT	

E3	**<Municipality> ICC Locations**	
Name	<Municipality> ICC Location	
Environment Entity ID	E3	
Description	<Municipality> ICC Location	
Attribute	Address	Address
	Phone	Phone
	Contact person	Contact person
Roles Involved	VICSES RDO	

E4	**Divisions location**	
Name	Divisions locations	
Environment Entity ID	E4	
Description	Divisions and Sectors location in the municipality	
Attribute	Address	Address
	Phone	Phone
	Contact person	Contact person

Roles Involved	<Municipality> IC	

E5	**Sectors location**	
Name	Sectors locations	
Environment Entity ID	E5	
Description	Divisions and Sectors location in the municipality	
Attribute	Address	Address
	Phone	Phone
	Contact person	Contact person
Roles Involved	<Municipality> IC	

E6	**Flood intelligence cards**	
Name	Flood intelligence cards	
Environment Entity ID	E6	
Description	Defining the flood intelligence cards	
Attribute	Type of information	Type of information
	Consequences	Consequences
Roles Involved	VICSES RDO	

E7	**Information and warnings communication methods**	
Name	Information and warnings communication methods	
Environment Entity ID	E7	
Description	Community information and warnings communication methods available	
Attribute	Lists of method type	Lists of method type
	Organization used	Organization used
Roles Involved	VICSES RDO	

E8	**List of media communication**	
Name	List of media communication	
Environment Entity ID	E8	
Description	List of media communication	
Attribute	Name	Name
	Contact number	Contact number
	Contact person	Contact person
Roles Involved	VICSES RDO	

E9	**Resources to provide emergency response**	
Name	Resources to provide emergency response	
Environment Entity ID	E9	
Description	Resources to provide emergency response	
Attribute	Type of resources	Type of resources
	Provided service	Provided service
Roles Involved	VICSES RDO	

E10	**Flood rescue resources**	
Name	Flood rescue resources	
Environment Entity ID	E10	
Description	Flood rescue resources availability	
Attribute	Type of resources	Type of resources
	Status resources	Status resources
Roles Involved	VICSES RDO	

E11	**Suitable airbase facilities' locations**	
Name	Suitable airbase facilities' locations	
Environment Entity ID	E11	
Description	Suitable airbase facilities' locations	
Attribute	Address	Address
	Region	Region
	Location details	Location details
Roles Involved	<Municipality> IC	

E12	**Essential Community Infrastructure and Property**	
Name	Essential Community Infrastructure and Property	
Environment Entity ID	E12	
Description	Essential Community Infrastructure and Property	
Attribute	The type	infrastructure or property's type
	The location	The location
	Address	Address
	Contact detail	Contact detail
Roles Involved	VICSES RDO	

E13	**Location of sandbag**	
Name	Location of sandbag	
Environment Entity ID	E13	
Description	Location of sandbag	
Attribute	Address	Address
	Region	Region
Roles Involved	VICSES RDO	

E14	**Designated local and regional roads, bridges, walking and bike trails**	
Name	Designated local and regional roads, bridges, walking and bike trails	
Environment Entity ID	E14	
Description	Designated local and regional roads, bridges, walking and bike trails	
Attribute	Address	Address
	Region	Region
	Details	Details
Roles Involved	VICSES RDO	
	VicRoads	
	<MunicipalityCouncil>	
	VICPOL	

E15	**The Dams locations**	
Name	The Dams locations	
Environment Entity ID	E15	
Description	The Dams locations	
Attribute	Address	Address
	Region	Region
	Detail	Detail
Roles Involved	VICSES RDO	
	DSE	

DISPLAN	Customised *scenario model* of the SES Victoria DISPLAN template
Country	Australia
Disaster Type	Flood
Phase	Response phase

6. *Customised scenario model of flood DISPLAN of the SES Victoria*

Scenario	S01
Name	**Arranging the response**
Goal	Arranging the response
Initiator	VIC SES <Regional> DO
Trigger	-
Pre-condition	Activated by the Regional Duty Officer (RDO) VICSES <Regional> or Incident Controller When the local resources are exhausted, the State's arrangements provide for further resources to be made available, firstly from neighboring Municipalities (on a regional basis) and then on a State-wide basis
Post-condition	-
Description	There are a number of agencies with specific roles that will act in support of VICSES and provide support to the community in the event of a serious flood within the <Municipality>.

Condition	**Step**	**Activity**	**Role**	**Environment Entity**

Sequential	1	Activating the response actions	R1	E1
	2	Arranging the activation	R1	E1
	3	Activating the agencies	R1	E1
	4	Providing support	R1	E1
	5	Providing support to VIC SES	R1	E1
	6	Providing support to community within <Municipality>	R1	E1
	7	Listing all the agreed roles of the involved agencies	R1	E1
	8	Establishing the <Municipality> Emergency Coordination Centre (MECC)	R1	E1
	9	Coordinating the escalation of flood incident	R1	E1

Scenario	S02			
Name	Providing strategic control priorities			
Goal	Providing strategic control priorities			
Initiator	<Municipality> IMT			
Trigger	-			
Pre-condition	-			
Post-condition	-			
Description	-			
Condition	**Step**	**Activity**	**Role**	**Environment Entity**
Sequential	1	Protection and preservation of life	R2	E2
	2	Protection safety personal	R2	E2
	3	Protection community and tourist	R2	E2
	4	Issuing of community information	R2	E2
	5	Issuing of community warnings	R2	E2
	6	Protection of critical infrastructure and community assets	R2	E2
	7	Protection of residential property	R2	E2
	8	Protection of individual livelihoods and economic production	R2	E2
	9	Protection of environmental and conservation	R2	E2
	10	Determining the priorities	R2, R3	E2
	11	Consult with SC and relevant stakeholders	R2, R3, R4	E1, E2

Scenario	S03			
Name	**Arranging Command, Control & Coordination**			
Goal	Arranging Command, Control & Coordination			
Initiator	VICSES <Regional> DO			
Trigger	All flood response activities within the <Municipality> including those arising from a dam failure or retarding basin / levee bank failure incident will therefore be under the control of the appointed Incident Controller, or his / her delegated representative			
Pre-condition	-			
Post-condition	-			
Description	The Command, Control and Coordination arrangements in this Municipal Flood Emergency Plan must be consistent with those detailed in State and Regional Flood Emergency Plans. The specific details of the Command, Control and Coordination arrangements for this plan are to be provided in Appendix C			
Condition	**Step**	**Activity**	**Role**	**Environment Entity**
Interleave	1	Controlling the response	R1	E1, E3
	2	Controlling the response of the flood activities	R1, R2	

	3	Appointing the IC to command and controller	R1	E1, E3
	4	Advising the VICSES to appoint the <Municipality> IC	R1, R5	
	5	Establishing an <Municipality> Incident Control Centre (ICC)	R1	
	6	Pre-determining Incident Control Centre locations	R1	
	7	Activating the <Municipality> ICC	R1	
	8	Establishing Divisions and Sectors	R1	E1, E4, E5
	9	Pre-determining divisions locations	R1	E1, E4, E5
	10	Pre-determining sectors locations	R1	E1, E4, E5
	11	Establishing the EMT	R1, R2	
	12	Providing an Emergency Management Liaison Officer (EMLO)	R1	
	13	Providing other staffs and / or resources to the EMT	R1	
	14	Taking actions to response the flood warnings	R1	
	15	Reviewing flood information	R1	
	16	Monitoring weather and flood information - www.bom.gov.au	R1	
	17	Assessing Command and Control requirements	R1	
	18	Review and consider local resources	R1	
	19	Notify and brief appropriate officers	R1	
	20	Assessing ICC readiness	R1	
	21	Ensure flood bulletins and community information	R1	
	22	Monitor and undertake watercourses reconnaissance	R1	
	23	Develop media and community information management strategy	R1	
	24	Ensure flood mitigation are being checked	R1	
	25	Develop and issue incident action plan	R1	
	26	Develop and issue situation report	R1	
	27	Develop an appreciation of current flood and predicted levels	R1	
	28	Review flood intelligence	R1	
	29	Determining what the at-risk community need to know	R1	
	30	Warning the at-risk community including	R1	
	31	Liaising with relevant asset owners	R1	
	32	Implementing response strategies	R1	
	33	Continuing to monitor the flood situation – www.bom.gov.au/vic/flood/	R1	
	34	Continuing to conduct reconnaissance	R1	

Scenario	S04
Name	Distributing of community information and warnings
Goal	Distributing of community information and warnings
Initiator	VICSES <Regional> DO
Trigger	All flood response activities within the <Municipality> including those arising from a dam failure or retarding basin / levee bank failure incident will therefore be under the control of the appointed Incident Controller, or his / her delegated representative
Pre-condition	-
Post-condition	-
Description	-

Condition	**Step**	**Activity**	**Role**	**Environment Entity**
Sequential	1	Releasing of flood bulletins and information	R1	
	2	Assisting the VICSES to warn individuals within the community	R1, R2	E4
	3	Informing public and media briefing	R1	
	4	Communicating of community flood warnings	R1	
	5	Requesting to assist VICSES	R1	

	6	Assisting to communicate warnings	R1, R8, R9,R10	
	7	Using the EAS and SEWS to evacuate	R1, R2	
	8	Coordinating the information of public health and safety precautions	R1, R7	E4

Scenario	S05
Name	Managing media communication
Goal	Managing media communication
Initiator	<Municipality> IC
Trigger	All flood response activities within the <Municipality> including those arising from a dam failure or retarding basin / levee bank failure incident will therefore be under the control of the appointed Incident Controller, or his / her delegated representative
Pre-condition	Establishing the ICC to manage Media communication
Post-condition	-
Description	-

Condition	**Step**	**Activity**	**Role**	**Environment Entity**
	1	Managing all Media communications	R2, R11	

Scenario	S06
Name	Assessing a rapid impact
Goal	Assessing a rapid impact
Initiator	VICSES <Regional> DO
Trigger	When flooding is expected to be severe enough to cut access to towns, suburbs and/or communities
Pre-condition	-
Post-condition	-
Description	-

Condition	**Step**	**Activity**	**Role**	**Environment Entity**
Interleave	1	Assessing and record the extent and nature of damage	R1	E8,E9
	2	Providing the basis for further needs assessment	R1	
	3	Providing the basis for a recovery planning	R1, R12	

Scenario	S07
Name	**Arrange Warning Service Operations**
Goal	Arrange Warning Service Operations
Initiator	SESLHQ
Trigger	When flooding is expected to be severe enough to cut access to towns, suburbs and/or communities
Pre-condition	Required to provide emergency response
Post-condition	Emergency response has been provided
Description	-

Condition	**Step**	**Activity**	**Role**	**Environment Entity**
Sequential	1	Consulting to ensure that resources are in place	R2	
	2	Providing emergency response	R2	

Scenario	S08
Name	**Response to Flash Flooding**
Goal	Response to Flash Flooding
Initiator	<Municipality> IC
Trigger	All flood response activities within the <Municipality> including those arising from a dam failure or retarding basin / levee bank failure incident will therefore be under the control of the appointed Incident Controller, or his / her delegated representative
Pre-condition	-
Post-condition	-

Description		Emergency management response to flash flooding should be consistent with the guideline for the emergency management of flash flooding contained within the State Flood Emergency Plan		
Condition	**Step**	**Activity**	**Role**	**Environment Entity**
Sequential	1	Conducting pre-event planning	R2	E12
	2	Determining barriers to evacuation	R2	
	3	Determining adopted strategy	R2	
	4	Determining contingency plan	R2	E17
	5	Assessing public information capability	R2	
	6	Providing safety advice	R2	
	7	Advising to seek the highest point	R2	
	8	Advising them not to attempt to flee by entering floodwater	R2	
	9	Calling 000	R2	
	10	Establishing earlier evacuation trigger	R2	
	11	Making specific preparations	R2	
	12	Establishing evacuation (relief) centres	R2	

Scenario		S09		
Name		**Evacuation**		
Goal		Evacuation		
Initiator		<Municipality> IC		
Trigger		-		
Pre-condition		Recommending or warn people to prepare to evacuate or to evacuate immediately		
Post-condition		-		
Description		-		
Condition	**Step**	**Activity**	**Role**	**Environment Entity**
Interleave	1	Recommending or warning people to evacuate immediately	R2	E13
	2	Management of the evacuation process	R2	E17
	3	Assisting the evacuation process	R1-R19	
	4	Developing and communicating the evacuation warnings	R2, R1	
	5	Registering people affected by a flood	R2, R1, R13	

Scenario		S10		
Name		Flood Rescue		
Goal		Flood Rescue		
Initiator		VICSES <Regional>DO		
Trigger		All flood response activities within the <Municipality> including those arising from a dam failure or retarding basin / levee bank failure incident will therefore be under the control of the appointed Incident Controller, or his / her delegated representative		
Pre-condition		Rescue operations may be undertaken where voluntary evacuation is not possible, has failed or is considered too dangerous for an at-risk person or community		
Post-condition		-		
Description		Appropriately trained and equipped VICSES units or other agencies that have appropriate training, equipment and support may carry out rescues		
Condition	**Step**	**Activity**	**Role**	**Environment Entity**
Interleave	1	Undertaking a dynamic risk assessment	R1	E14
	2	Assessing of the availability flood rescue resources	R1	E15
	3	Support the flood rescue	R1	

	4	Conduct the flood rescue	R1	

Scenario	S11
Name	**Managing the aircraft**
Goal	Managing the aircraft
Initiator	<Municipality> IC
Trigger	When evacuation is required
Pre-condition	Requesting aircraft support through the State Air Desk
Post-condition	-
Description	Aircraft can be used for a variety of purposes during flood operations including evacuation, resupply, reconnaissance, intelligence gathering and emergency travel

Condition	**Step**	**Activity**	**Role**	**Environment Entity**
Sequential	1	Controlling air support operation	R2	
	2	Requesting air support operation	R2	
	3	Locating air base management	R2	

Scenario	S12
Name	Resupplying
Goal	Resupplying
Initiator	VICSES <Regional> DO
Trigger	When predictions/intelligence indicates that communities, neighbourhoods and/or households may become isolated
Pre-condition	Communities, neighbourhoods or households can become isolated during floods as a consequence of road closures or damage to roads, bridges and causeways. Under such circumstances, the need may arise to resupply isolated communities/properties with essential items.
Post-condition	-
Description	Communities, neighbourhoods or households can become isolated during floods as a consequence of road closures or damage to roads, bridges and causeways. Under such circumstances, the need may arise to resupply isolated communities/properties with essential items.

Condition	**Step**	**Activity**	**Role**	**Environment Entity**
Interleave	1	Arising to resupply isolated communities	R1	E14
	2	Advising to stocking up on essential items	R1	
	3	Supporting the isolated communities		
	4	Assisting with the transport of essential items		
	5	Assisting with the logistic function		
	6	Including the resupply to the emergency relief arrangements		

Scenario	S13
Name	**Protecting essential Community Infrastructure and Property**
Goal	Protecting essential Community Infrastructure and Property
Initiator	<Municipality> IC
Trigger	-
Pre-condition	The Incident Controller will determine the priorities related the use of sandbags , which will be consistent with the strategic priorities
Post-condition	-
Description	Essential Community Infrastructure and Property (e.g. residences, businesses, roads, power supply etc.) may be affected in the event of a flood

Condition	**Step**	**Activity**	**Role**	**Environment Entity**
Sequential	1	Maintaining a small stock of sandbags	R2, R6	
	2	Backing up supplies	R2, R6	
	3	Determining the priorities related the use of sandbags	R2	
	4	Giving protection of Essential Community Infrastructure	R2, R1	
	5	Protecting the priorities	R2	
	6	Sandbagging to minimise entry of water	R2	

	7	Encouraging businesses and households	R2	E18
	8	Consulting of temporary levees	R2, R14, R15, R10	
	9	Construction of temporary levees	R2	
	10	Ensuring to keep advised of the flood situation	R2	
	11	Keeping to inform the status to Incident Controller	R2, R16	

Scenario	S14
Name	Arranging disruption services
Goal	Arranging disruption services
Initiator	<Municipality> IC
Trigger	
Pre-condition	Should only be used if other transport means are not available or not suitable
Post-condition	-
Description	Disruption to services other than essential community infrastructure and property can occur in flood events

Condition	**Step**	**Activity**	**Role**	**Environment Entity**
		Arranging to respond the service disruption in <Municipality >	R2	

Scenario	S15
Name	Carrying out road closures
Goal	Carrying out road closures
Initiator	<Municipality> IC
Trigger	-
Pre-condition	During periods of flooding many rural properties and some villages can become isolated
Post-condition	-
Description	-

Condition	**Step**	**Activity**	**Role**	**Environment Entity**
Interleave	1	Observing and placing of warning signs	R2, R17	
	2	Liaising with VicRoads of erecting warning signs, closing roads and bridges	R2, R17	
	3	Advising the VicRoads of erecting warning signs, of closing roads and bridges	R2	
	4	Designating main roads and highways	R2, R17	
	5	Designating local and regional road network	R2, R6	
	6	Communicating information regarding road closures	R2, R6, R17	

Scenario	S16
Name	Controlling DAM failures
Goal	Controlling DAM failures
Initiator	DSE
Trigger	During periods of flooding many rural properties and some villages can become isolated
Pre-condition	-
Post-condition	-
Description	Major dams with potential to cause structural and community damage within the Municipality are contained in Appendix A

Condition	**Step**	**Activity**	**Role**	**Environment Entity**
		Controlling for DAM safety incidents	R9	

Scenario	S17
Name	Responsible Waste Water and Critical Sewerage Assets

Goal	Responsible Waste Water and Critical Sewerage Assets
Initiator	DSE
Trigger	Flood waters can strand travellers
Pre-condition	-
Post-condition	-
Description	Inundation of critical sewerage assets including septic tanks and sewerage pump stations may result in water quality problems within the Municipality

Condition	Step	Activity	Role	Environment Entity
	1	Advising VICSES of the security of critical sewerage assets	R9	
	2	Maintaining or improving the security	R9	
	3	Checking and correcting the operation of critical sewerage assets	R9	
	4	Advising the ICC	R9	
	5	Inspecting and reporting on any water quality issues	R9, R11, R18, R19	

Scenario	S18
Name	Reviewing after action
Goal	Reviewing after action
Initiator	VICSES <Regional>DO
Trigger	-
Pre-condition	-
Post-condition	-
Description	VICSES will coordinate the after action review arrangements of flood operations as soon as practical following an event

Condition	Step	Activity	Role	Environment Entity
Sequential	1	Coordinating the after action review arrangements	R1	
	2	Representing at the after action review	R1	