METAMODEL-BASED DECISION SUPPORT SYSTEM FOR DISASTER MANAGEMENT

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Abstract: Generally software model developers use a general purpose language such as Unified Modelling Language (UML) in modelling their domain application models. But when they come to the situation in which the models they create do not perfectly fit the modelling needs as they desire, a more specific domain modelling language offers a better alternative approach. In this paper, we create a Disaster Management (DM) metamodel that can be used to create a disaster management language. It will serve as a representational layer of DM expertise leading to a DM decision support system based on combining and matching different DM activities according to the disaster on hand. A creation process of the metamodel is presented leading to the synthesis of initial metamodel, as a main component to create a decision support system to unify, facilitate and expedite access to DM expertise.

1 INTRODUCTION

Various kinds of modeling languages have been applied in different disciplines including systems engineering (Weilkiens, 2008), software engineering, information management, computer science and business process modelling. In this research we study disaster management (DM) as a specific domain, where its own language will be modelled. Through this paper, we develop a DM metamodel as a precise definition of the constructs and rules needed for creating the semantic models of this domain. Generally, who the users are of a metamodel depend on the type of created metamodel. Traditionally users will be among CASE tool vendors, modelling tool vendors, method engineers, repository vendors, system integrators, researchers and end users. In this context, *end users* would include emergency managers, disaster management coordinators or safety managers for various public and private organizations seeking to create a DM model to manage anticipated disasters.

The increasing number of disasters recently, such as earthquakes, tsunamis, floods, bushfires, air crashes, epidemic, have posed a huge challenge not only to population at large, but also to public services and agencies tasked with activities relating to preventing and managing disaster responses. Recent failures can be easily identified in the management of the Swine-Flu (H1N1) pandemic hitting Australian shores in large numbers through cruise ships or in the devastating communication failures in the recent bushfires in Victoria (Australia). Many such failures are due to expertise not being available in a timely manner. This is partly due to inability to recognize and identify correct expertise, as it is often perceived as too tied to kinds of events (floods, bushfires, tsunamis, pandemic or earthquake). Potential for reusing expertise is often overlooked leading to catastrophic consequences. In this paper, we present an approach to unify DM knowledge to create a DM Decision Support System (DSS) that combines and matches different DM activities to suit the disaster on hand by using the DM metamodel.

The approach proposed in this paper is inspired by a software engineering knowledge management practice known as *method engineering* (Brinkkemper, 1996) which involves storing various software methodologies as a collection of reusable process fragments for later reuse to create hybrid methodologies as new software development projects arise. In DM, the first step and the focus of this paper are to appropriately represent DM knowledge and to warehouse DM knowledge in an

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appropriate form to later allow mixing and matching DM experiences. The appropriate representation of DM knowledge will enable the creation of a repository of DM experiences. Interfacing this to a DSS that takes as input new disaster parameters, will assist in deciding the best DM approach by combining various actions from previous DM experiences.

2 RELATED WORKS

Failures in preventing disasters or failures in their subsequent management are rarely caused by a single factor. They are often due to an accumulation of complex chain of events and often accompanied by changes in external environment factors (Aini, Fakhrul-Razi et al., 2005). Hence, it is common wisdom that no two disasters are exactly the same, and that every disaster requires its own management process. However, the way disasters impact human lives and business processes may well be similar and responses are often transferrable between disasters. Evacuation of personnel for example is a DM action that is applicable in many disaster situations. This paper aims to use a generic representational layer (a metamodel) to give a unified view of common concepts and actions that apply in various disasters. We use existing DM and security models (Asghar, Alahakoon et al., 2006; Russo, Raposo et al., 2006; Benaben, Hanachi et al., 2008; Beydoun, Low et al., 2008; Kruchten, Monu et al., 2008; Beydoun, Low et al., 2009) and DM literature produced by World Health Organisation and Emergency Management Australia, as a starting point towards creating a repository of past DM experiences to be stored as reusable components and expressed using concepts identified in a generic DM metamodel. This will be the first to create a DSS to enable formulating DM approaches as new situations arise.

Our work also draws on research from method engineering (Brinkkemper, 1996) and metamodelling (Nordstrom, Sztipanovits et al., 1999). Method engineering is an application of knowledge based technology underpinned by software engineering results for completion of knowledge representation and acquisition. Metamodelling, a central activity promoted by the efforts of the Object Management Group (OMG) (Object Management Group (OMG), 2003), has also been promoted in method engineering. It aims to create interoperable, reusable, portable software activities and components. In this context, a metamodel is a fundamental building block that makes statements about the possible structure of models (Stahl, Voelter et al., 2005). It is usually defined as a set of constructs of a modelling language and their relationships, as well as constraints and modelling rules without necessarily the concrete syntax of the language (Beydoun, Low et al., 2009). We use metamodelling in our work to develop existing tentative attempts to represent DM knowledge in a reusable form to give a unified point of access supported by an intelligent DSS. In particular, we illustrate our unification approach by presenting an initial metamodel that we believe could generalize most of the concepts used in existing DM models.

3 METAMODEL-BASED DM KNOWLEDGE MANAGEMENT

DM is defined as a management of all aspects of planning and responding to all phases in disaster as illustrated in Table 1. These phases include *mitigation, preparedness, response* and *recovery* activities (W3C Incubator Group, 2008). This definition includes the management of risks and consequences of a disaster. Large disasters cut across many boundaries including organizational, political, geographical, topical and sociological. This presents serious challenges in interoperability between various teams and creates difficulties in collaboration and cooperation across authorities, countries and systems. Moreover, data collection and integration problems arise as various technologies and tools are typically involved in data gathering and monitoring e.g. Global Positioning Systems (GPS), Geographical Information Systems (GIS), data collection platforms and early warning systems. A solid, general and global framework for coordinating people involved and interoperates with data, during and after disaster through is still inadequate.

In metamodelling DM knowledge, we uncover and make explicit key aspects of activities, cooperation and components in DM. Surveying a number of existing DM models (shown in Table 1), we observe that some concepts represent a similar DM activities which are expressed differently. For example, in a Circular Model for Disaster (Kelly, 1998), the terminology '*Emergency Response*' is being used to represent the response and rescue activity of disaster victims. But, the same activity however is represented by using '*Emergency State'* in Ibrahim-Razi Model in (Shaluf, 2008).

Table 1: DM concepts used to represent various DM activities in existing disaster models.

Author	Model	DM Phase			
		Mitigation	Preparedness	Response	Recovery
In (Kelly, 1998)	Circular Model for Disaster	*Disaster mitigation*	*Disaster prevention, Disaster preparedness*	*Warning, Disaster, Emergency response*	*Rehabilitation, Reconstruction, Development*
In (Tierney, Lindell et al., 2001)	Disaster Phases and Time Period Model	*Hazard vulnerability, Hazard mitigation*	*Emergency preparedness*	*Emergency response*	*Disaster recovery*
In (Manitoba Health Disaster Management, 2002)	Integrated Disaster Management Model	*Hazard assessment, Strategic plan, Mitigation*	*Risk management, Preparedness*	*Response*	*Monitoring and evaluation*
In (Doherty, 2004)	An Emergency Management Model for Home Health Care Organizations	*Mitigation*	*Preparedness*	*Response*	*Recovery*
In (Ahmed, 2008)	Expand-Contract Model	*Prevention and mitigation strand*	*Preparedness Strand*	*Relief and Response Strand*	*Recovery and Rehabilitation Strand*
In (Asghar, Alahakoon et al., 2006)	A Comprehensive Conceptual Model For Disaster Management	*Hazard assessment, Strategic planning, Mitigation*	*Risk management, Preparedness*	*Response*	*Recovery, Monitoring and evaluation*
In (Shaluf, 2008)	Ibrahim-Razi Model	*Inception of errors, Accumulation of errors*	*Warnings, Disaster impending stage, triggering event*	*Emergency state, Disaster*	*Normal state*
In (Ahmed, 2008)	Traditional DM Cycle Model	*Mitigation*	*Preparedness*	*Disaster Impact*	*Reconstruction, Rehabilitation*

Managing and sharing knowledge of this complex domain is hard. A unified metamodel can ensure that key concepts are easily presented to newcomers and can increase portability of various models across supportive modelling tools. It can also create better communication amongst practitioners and research could then focus on improving and/or realizing a unified body of knowledge (Beydoun, Low et al., 2009). Advantages of metamodel developed in this paper are as follows:

- Facilitating global communication among different disaster emergency users as the metamodel has generalized all the concepts that must exist in this domain.
- Simplifying teaching new created model of this domain among the model users through a set of syntax and semantic rules provided.
- Providing guidelines for creating a comprehensive disaster management model which can cover the whole phases of DM (e.g: *Earthquake Emergency Response Model* - Response phase and *Bushfire Risk Reduction Model* - Mitigation phase).
- Enabling users to create new customised DM model based on choosing and combining sets of concept component based on their own model requirement.
- Highlighting scope for improvement in a DM practice through validation against other DM metamodels.

3.1 A Metamodel-based DM Decision Support System

Developing a DM metamodel is our first step towards creating a DSS to unify, facilitate and expedite access to DM expertise. This metamodel will describe the various DM activities and desired outcomes and serve as a representational layer of DM expertise, enabling an appropriate DM DSS based to guide combining and matching different DM activities according to the disaster scenario on hand. The DM metamodel will be complemented with a *Disaster Retrieval Model* that will be used to choose appropriate procedures and suit with different kinds of disaster (natural or man-made) on hand. The computational architecture of our system and the integration of a DSS platform will be context independent. For instance, different countries have their own organization in coordinating and act as an advisory board for handling disaster activities.

Most countries have a government agency to manage major disasters. For example, in Australia there is EMA (*Emergency Management Australia*), in the USA there is FEMA (*Federal Emergency Management Agency*) in Canada there is the PSC (*Public Safety Canada*). Hence for the purpose of developing our DM metamodel, models of different DM activities as applied by different countries are to be combined and stored into one database namely *DM Activities Repository*. This will be a collection of organizational, operational, planning, logistics and administration procedures and policies executed by these countries through their DM processes. These will be identified and organized according to the DM metamodel consisting of common concepts used in all four disaster phases.

The generic DM metamodel based on identified common concepts is the *destination point* of scattered concepts used in many DM activities worldwide. A process towards concept generalization is applied to make our DM metamodel more applicable (described in the next section). Activities from different sources (and countries) will be stored as *Procedure Fragments* in the DM Activities Repository. The DSS will assist in deriving the best disaster procedure fragment solution according to the disaster on hand. It will use a set of rules that will specifically determine what is the best solution based on disaster description input entered by a user of the system (e.g: local disaster manager, emergency coordinator and researcher) and the repository.

We adapt a *Case-Based Reasoning* and a *Model-Based Reasoning* technique in the way we determine the best decision solution for our DSS system. In this system architecture, we integrate an exception tolerant technique (Gao and Xu, 2010) to handle any exception problems which may occurred during the enactment of this DM workflow. Some of the situations in disaster context which require the exception handling include:

- Hospital emergency department fails to get clear information concerning the location in which the actual disaster had happened;
- Commands receive from high authorities for coordination of emergency operations is vague;
- Emergency equipment and resource failures;
- Emergency Call Centre receives unclear disaster call information;
- GIS fails to acquire a real data from the disaster real location;
- Missing of DM policies and procedures in handling certain emergency operation or;
- Aid distributions fail to deliver.

To produce the DSS system and a populated DM knowledge repository, the first step is we construct the DM metamodel. Besides the metamodel, we classify and formulate all DM activities procedures into a unified repository. A knowledge based interfaced to the repository is developed in order to support a retrieval and integration of the procedure fragments. In the next section, we overview existing relevant metamodels and describe the process of formulating our DM metamodel, before the metamodel is presented in Section 4.

4 METAMODELLING PROCESS

In this section, we present details of our model creation process and all components which support its development. To create our DM metamodel, we adapt a metamodelling approach from the work used to develop a *Framework for Agent Modelling Language* (FAML) in (Beydoun, Low et al., 2008) and (Beydoun, Low et al., 2009). The approach of our metamodelling creation process consists of 7 main steps:

Step 1: Identifying models by using *Model Importance Factor* (MIF) to find the best collection of DM models;

Step 2: Extraction of general concepts relevant to all identified DM model which have been derived in Step 1 (Asghar, Alahakoon et al., 2006; Russo, Raposo et al., 2006; Benaben, Hanachi et al., 2008; Beydoun, Low et al., 2008; Kruchten, Monu et al., 2008; Beydoun, Low et al., 2009) will be reviewed in this section;

Step 3: Candidate concepts are short-listed;

Step 4: Differences between concepts are reconciled;

Step 5: Chosen concepts are designated into relevant sets

Step 6: Relationships among concepts are identified leading to the initial DM metamodel (Figure 1);

Step 7: Validating the metamodel.

4.1 Step 1: Identifying Models by using Models Selection Criteria (*Model Importance Factor*)

Existing models used to describe disasters provide a starting point to identify commonly used concepts in DM. Many disaster models have been developed by many researchers and organizations globally. To select a subset of 10 models for our metamodelling process, we formulate a criterion named as *Model Importance Factor* which its derived formula is as shown in (1). It calculates the weight to categorize which model is the most relevant to be chosen as required for Step 1 (model for relevant set) and Step 7 (model for validation) models. In developing the MIF, we adapt the idea of *Journal Impact Factor* measuring the frequency of which the average article in a journal has been cited in a particular year. Our MIF compare the impact of the models in the same domain. It is defined as follows:

T_{cited}	:	The total number of **T**imes the model or metamodel is *cited* (Paper & Journal); For a model appear in a publication without citation, default weight is set to: • Thesis - *10*; Report - *15*;
$Y_{current}$	:	The *current* **Y**ear calculation is made;
$Y_{published}$	:	The **Y**ear model is *published*;
E_{level}	:	Weight of **E**ffort is calculated based on *level* of model developer by using weight: • *0.1* - Individual; *0.2* - National Organization, *0.3* – International Organization;
$R_{coverage}$	:	The weight of **R**elevancy represents how pertinent and applicable the model to the DM metamodel development requirement;
Participant (**P**)	:	The number of **P**articipants involved in developing a model.

$$\mathbf{MIF} = \frac{(T_{cited} * (E_{level} * P) * R_{coverage})}{((Y_{current} + 1) - Y_{published}))} \tag{1}$$

In this formula, we set 6 criteria in categorizing which models contain the highest priority to be chosen as a set of best DM models. The first criterion is $\mathbf{T_{cited}}$ which indicates the total number of times the model is cited, specifically model comes from journal or conference paper. Except for a publication which cannot be determined its citation number, we set a default weight according to the types of the publication (e.g: Thesis is set 10 and Report produced by a government and other organization is set 15). Then this followed by determining the current year when the calculation is made through $\mathbf{Y_{current}}$ and the year when the model is published by $\mathbf{Y_{published}}$. Another criterion we set is $\mathbf{E_{level}}$ that will evaluates the weight of effort in which the level of model developer is calculated by using index of 0.1 for individual (e.g: university researcher), 0.2 for national organization (e.g: EMA) and 0.3 for international organization (e.g: WHO).

A weight of a total number of people involved in developing the model is also considered. To support this condition, **P** is constructed to represent the number of participants involved in developing the model. The last criterion we set is $\mathbf{R_{coverage}}$ to calculate the weight of how relevant, pertinent and applicable is the model to the DM metamodel development requirement. For example, a '*Manitoba Health Disaster Management Model'* (Manitoba Health Disaster Management, 2002) was set 0.3 weight contribution as it could cover most of the whole DM aspect in his model, whereas an '*Evacuation Model*' gets less weight compared to Manitoba model as it cover only a small portion from the whole DM domain concepts. Below is two sample of MIF calculation for Manitoba model (1.00), Russo model (MIF: 0.24) and Kructhen model (MIF: 0.12).

T_{cited}	$Y_{current}$	$Y_{published}$	$D_{standard}$	P	$R_{coverage}$	MIF
15	2010	2002	0.2	10	0.3	**1.00**
10	2010	2006	0.1	4	0.3	**0.24**
3	2010	2008	0.1	4	0.3	**0.12**

Even though we have set up the MIF criteria, we still consider a contribution from variety of sources in selecting a subset of DM models to be used in Step 1 process. For instance from thesis, government (state, country) or private organization reports, papers and journals. This to ensure that the metamodel we develop will not only consider an *academic impact* point of view (e.g: number of how many paper of model is cited) but it also includes *organization and government impact* such as from a government, private or any emergency organization reports.

4.2 Step 2: Selecting Concepts from Models

We implement manual extraction in deriving the concepts from each model we identify in step 1. Here we present some of the samples. The first metamodel we observe is Benaben's metamodel (Benaben, Hanachi et al., 2008) expressed using Web Ontology Language (OWL) and focuses on crises management. This metamodel elaborates a common and sharable reference model built to characterize crisis situations in three interrelated views namely *System, Treatment System* and *Crisis Description*. Benaben's metamodel covers the whole crisis characterization and collaborative processes that deal with it, aiming to integrate partners through information system interoperability. We derive 21 concepts from Benaben model. Some of them are *Collaborative Process, Procedure, Task of Actor, Actor on site, Event, Trigger, Crisis, Danger, Risk, Effect, Indicator, Gravity Factor, Civilian Society, People, Service of Actor* and *Resource.*

The second metamodel we use is Kruchten's (Kruchten, Monu et al., 2008) which conceptualises disasters as encompassing multiple stakeholder domains depicted in four main views: Disaster Visualization, Physical View, Communication and Coordination Simulator and Disaster Scenario. The metamodel aims to create a common language to communicate, analyze and simulate interdependencies about disaster scenario without having to disclose all critical and confidential data between parties involved. This metamodel attempts to unify the terminology sharpening the definition of terms and their semantic relationships.

The third metamodel we consider is Asghar's (Asghar, Alahakoon et al., 2006) which focuses on the arrangement of disaster activities in a logical sequence. This metamodel is built by linking disaster management actions with hazard and risk assessment activities. The model also incorporates environmental conditions, making it possible to analyse and separate the environmental issues from a disaster. And from this metamodel we derive 12 concepts including *Strategic planning, Risk Management, Mitigation, Preparedness, Response, Recovery, Early warning, Resource management, Environmental affects, Damage assessment, Coordination* and *Hazard assessment.* Another metamodel we use is Russo's (Russo, Raposo et al., 2006) which focuses on configuring collaborative virtual workspaces specifically in DM of oil and gas offshore structures. It investigates how a distributed workspace environment can support DM involving distributed collaborative technical teams to work as a collaborative virtual team. This metamodel is focused on one-specific-disaster approach.

Targeting a generic metamodel in our work is inspired by (Beydoun, Low et al., 2008) and (Beydoun, Low et al., 2009), where a generic metamodel was developed for representing and securing Multi Agent System (MAS). In fact, several generic security concepts identified in (Beydoun, Low et al., 2008) have their equivalent in DM. For example, recovering from an intrusion attack in a MAS requires restoring data logs. Analogies to this exist in restoring many lost community services in disaster scenarios, requiring maintaining back up organizational structures. Our work takes DM modelling a step further aiming to generalize various types of DM activities concepts into one generic encompassing metamodel.

4.3 Step 3: Short-listed Candidate Concepts

The collection of existing DM models that we have revised, assist us towards deriving the common concepts used in all these models. It gives a total of 55 common concepts from 5 models we identified and will be reconciled in the step 4.

4.4 Step 4: Reconcile Difference between Concepts

In step 4, we reconcile differences between definitions where possible. In choosing the common concept definition to be used, study to all definition of concepts that we have derived is crucial. If there is a contradictory use of concept definition between two or more sources occurs, then a process to harmonize and fit the definition in the metamodel is required. As for an example, a concept of *People* is defined differently in a few models. Benaben defined it as '*All the group of persons which can be threatened by the crisis situation*', but in Kructhen model, the concept is defined as '*Cell that contains people*'. Thus we will choose the definition used by Benaben model as it fits our metamodel. Below are a few examples of concept and its definition:

i) ***Event*** - An incident or situation, which occurs in a particular place during a particular interval of time.
ii) ***Effect*** - An event that can produce other effects or a noticeable consequence of a disaster.
iii) ***Risk*** - The potential disaster losses, in lives, health status, livelihoods, assets and services, which could occur to a particular community or a society over some specified future time period.
iv) ***Disaster*** - A situation where serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources.

4.5 Step 5: Designate Chosen Concept into Relevant Sets

In Step 5, a process of designating all derived and reconciled concepts is performed according to theirs respective set. In DM metamodel, we choose to present them in one layer which encompassing all DM concepts that we have processed. Figure 1 illustrates each of these concepts.

4.6 Step 6: Define Relationships among Concepts

After combining all DM concepts to its designated diagram, the relationships exist among the concepts are then created. For instance, between *Disaster* and *ElementsAtRisk* concept, we set the *Association* relationship by using (——) symbol with '*AffectWellness*' to indicate that a disaster could affect all elements which are at risk by a disaster. A *Specialization* relationship (—▷) is used to signify that *Civilian societies*, *Infrastructures, Natural sites* and *People* are components which is categorized as '*is a kind*' of the elements.

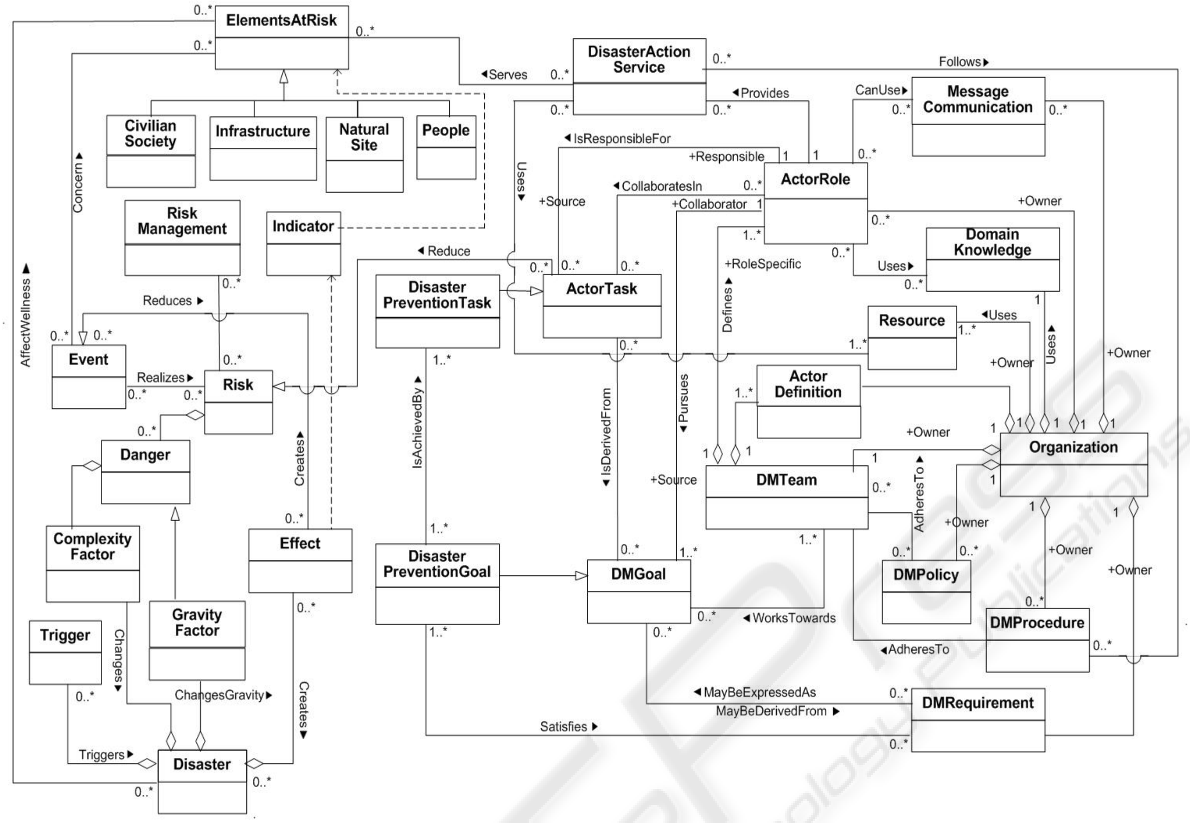

Figure 1: DM Metamodel proposed.

4.7 Step 7: Validation

Validity threats to the resultant metamodel are internal and external. The creation process ensures that internal threats are resolved and that the metamodel is consistent and coherent. However, to deal with external threats, it is important to ensure that the metamodel is capable of generating a wide range of DM models. This threat is currently being dealt with by ensuring that the metmaodel can generate 10 models which were not used in its construction. This validation is not part of this paper.

5 RESULTANT DM METAMODEL

In this section we represent our initial DM metamodel as the output in which Steps 1 to Step 6 processes as (described in Section 4) are iteratively applied into it and also the refinement of this metamodel. Our resultant metamodel contains the relationships among concepts which can represent the semantic of the domain as shown in Figure 1.

The core class in this DM Metamodel is the *Organisation* which represents the loose 'organisation' where DM concepts are operationalised. All key concepts in DM are grouped in the *Organisation* concept. Other key DM concepts are aggregated within this class and they include: *DMProcedure, DMRequirement, DMPolicy, Actor, DMTeam, DomainKnowledge, Resource, ActorRole* and *MessageCommunication*. *DMProcedure* can represent the collections of implemented procedures of DM activities including for example Mitigation, Preparedness, Rescue, Response and Evacuation. *DMTeam* defines a collection of *ActorRole* class which typically describes human roles that work towards a *DMGoal*. *ActorTask* class in our metamodel *is derived* from a *DMGoal* class. Here we also model a *DisasterPreventionGoal* as a class that can be achieved by *DisasterPreventionTask.*

Some of the classes from the crisis metamodel developed by Benaben in (Benaben, Hanachi et al., 2008) is taken into consideration while we develop the model of the actual disaster event (left hand side of Figure 1). To model this, we grouped all components consisting of *People, Infrastructure,* *NaturalSite* and *CivilianSociety* into *ElementsAtRisk*. We introduced the '*is a kind of*' (specialization) relationships which tied up these four components with *ElementsAtRisk* class. Thus, *DisasterActionService,* a class of collaboration among several actors will provide support and help to this affected group of elements through the *ElementsAtRisk* class. Disaster, a tragedy that affects this *ElementsAtRisk* typically occurs due to accumulation factors represented by a *Trigger* and have consequences that are described by *Effect* and vary in intensity represented by *ComplexityFactor* and *GravityFactor*.

The metamodel is generic and generalizes various kinds of disaster concepts that can be refined according to the context on hand. It explicitly covers the management of disaster in all four different phases including *mitigation, preparedness, response* and *recovery*. We anticipate that various concepts in DM, their relationships and attributes, different types of data models can be generated using refinement of concepts in this metamodel.

5.1 Refinement of DM Metamodel: Bushfire Disaster Case Study

To illustrate and validate the semantics of our metamodel concepts, we refine concepts described into the scenario of the recent bushfire disaster in Marysville (Victoria, Australia) (shown in Table 2). It illustrates the refinement of concepts we proposed in our DM metamodel in a specific disaster domain.

As a result, Figure 2 shows the corresponding refinement in a diagram, illustrating the independence of our metamodel from any specific disaster metamodel. It can be used to derive one of many possible disaster models. Figure 2 is one of many models that could be derived by using the DM metamodel. For this bushfire model, it shows us various factors caused this tragedy in Marysville come from a combination of a hot weather temperature (47 Celsius), low humidity level calculated by using Fire Danger Index (less than 6%), strong north-westerly wind (with average 100 km/h) and an extremely dry of fuel moisture in Marysville bushland area. All these combination are identified as an example for the *GravityFactor* concepts we introduced in our DM metamodel. Whereas, a *GlobalClimateChange* is an instance of *ComplexityFactor* in this case. Hence, a combination of *GravityFactor* and *ComplexityFactor* concepts will contribute to a result of bushfire factors. In this model, the tragedy is made from a combination of a factors comes from *BushfireFactor* concept.

Table 2: A refinement of DM metamodel concepts to a specific-domain disaster (Bushfire in Marysville, Victoria).

	DM Metamodel Concept	Bushfire Disaster Concept
1	***DMProcedure***	*BushfireProcedure (e.g: EvacuationProcedure and FirstAttackFireProcedure)*
2	***DMPolicy***	*BushfirePolicy (ex: Bushfire-RecoverPolicy, RescuePolicy, PreparednessPolicy)*
3	***ActorDefinition***	*EmergencyTeam*
4	***DMTeam***	*MarysvilleBushfireTeam*
5	***Domain Knowledge***	*BushfireDomainKnowledge*
6	***Resource***	*MarysvilleWaterResource, FireFightingResource*
7	***ActorRole***	*RescueTeamRole*
8	***Message Communication***	*StateWeatherofBureau*
9	***People***	*MarysvillePeople*
10	***DMGoal***	*BushfireManagementGoal*
11	***ActorTask***	*RescueTask (eg: FireServiceTask, HealthDepartmentTask)*
12	***Disaster PreventionTask***	*BushfirePreventionTask*

The *BushfireDisaster* concept then affects the *MarysvilleAffectedElement* including its infrastructure (e.g: schools, shops, roads), natural site (e.g: river, tree), civilian society (e.g: local communities) and also people in Marysville. The specific model (shown in Figure 2) suggests that to create such a comprehensive DM organization a few elements are required to this main concept. Those elements are such DM policy (through *BushfirePolicy*), various DM resources (e.g: *BushfireRescueResource* and *MarysvilleWater Resource*), emergency rescue team (as *MarysvilleBushfireTeam),* role of emergency actor (as *BushfireRescuerRole*), DM procedure (as *BushfireProcedure* – with the example of fire attack procedure and evacuation procedure in bushfire case), and DM requirement (*BushfireManagement Requirement*).

This organization ideally can make use of an ontology of bushfire disaster (*BushfireDomain Knowledge*) to support the DM team. *BushfireManagementGoal* is a concept represents our *DMGoal*. It is a specification of the state where DM tries to achieve. This concept can be derived from an action task conducts by emergency rescue team. Thus, this situation is represented through *RescueTask* concept which contains '*IsDerivedFrom*' relationship to *Bushfire ManagementGoal* concept. The model (of Figure 2) also shows that bushfire risk can be reduced by performing a rescue task action. Then, *BushfireActionService* is a concept which representing the service provided by a rescue actor.

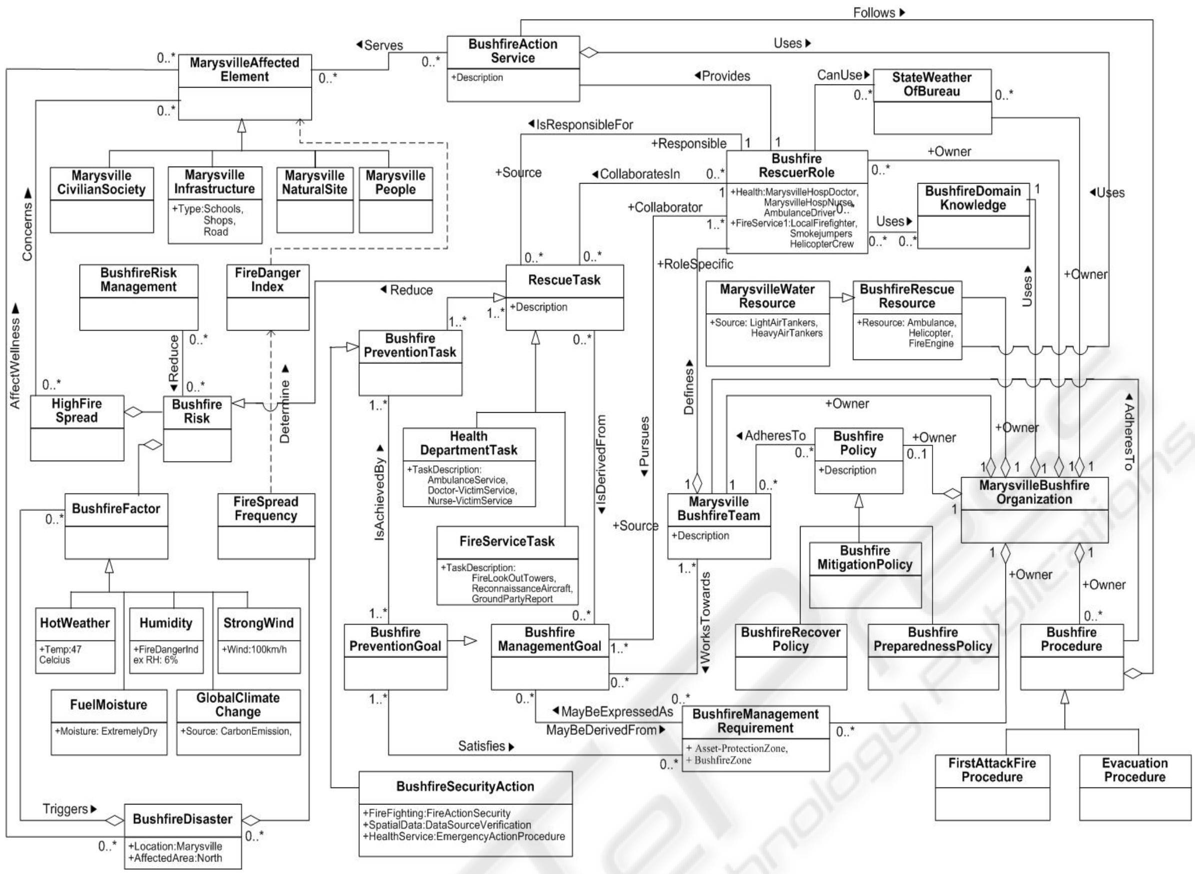

Figure 2: Metamodel refinement, a model of bushfire disaster in Marysville, Victoria, Australia.

With the aims to drive the disaster situation to a more stable and handled state, they provide (through '*Serves*' relationship) their rescue service (*BushfireActionService*) to the components which exposed to a disaster (*MarysvilleAffectedElement*).

During refinement of the metamodel, if there is any difference occur to the original components of the metamodel such as any process of adding new, changing or even deleting any current class in new model created by the user, all these cases will be stored in system repositories (Heicke, 2009). As discussed by Heicke, who studied the difference, changes in metamodel, suggesting that to represent difference in metamodel, every modelling element of the original metamodel need to have options of insertion, deletion or modification. It could be done by constructing new constrains and rules in managing the situation. Therefore, by implementing this process the evolution of the metamodel could be recorded accurately and precisely. We also adapt this process to manage all dynamic issues occur in our metamodel.

6 CONCLUSIONS

In this paper, we have illustrated a novel approach in modeling a disaster management language through DM Metamodel. We observed that many existing disaster models are not based on any standard metamodel but rather constitute proprietary solutions mainly focused on frameworks and other model example aspects. An important task of these works is the construction of navigation metamodel from the conceptual data of DM model. In order to simplify this activity, we have proposed DM metamodel that can describes all contained DM model concepts and the way they are arranged, related and constrained. We presented the Metamodel-based DM DSS architecture where the DM metamodel will be used to represent, store and later retrieve DM knowledge.

As a proof of concept, we presented our first version of this metamodel and showed refinement of its concepts in the domain of bushfires in particular the recent tragic bushfires in Victoria. Also, we have discussed several application scenarios in which our metamodel provides a valid support. We are currently working on a more comprehensive validation which will involve taking 20 existing DM models and ensure that our metamodel can be refined to generate all of them. There are some issues that need to be investigated to fully realize the potentiality of this approach. These include: (i) a complete set of rules, processes and methodologies for instantiation of user domain models; (ii) the limitations of the metamodel; (iii) tools exist to facilitate the development and use of the domain model and (iv) methodology exist in validating the user domain models.

REFERENCES

Ahmed, I. (2008): Disaster Risk Management Framework. *International Training Workshop on Disaster Risk & Environmental Management,* Melaka, Malaysia.

Aini, M. S., A. Fakhrul-Razi, M. Daud, N. M. Adam and R. A. Kadir (2005): Analysis of Royal Inquiry Report On The Collapse Of A Building In Kuala Lumpur: Implications For Developing Countries. *Disaster Prevention and Management,* 14 (1): 55-79.

Asghar, S., D. Alahakoon and L. Churilov (2006): A Comprehensive Conceptual Model for Disaster Management, *Journal of Humanitarian Assistance*.

Benaben, F., C. Hanachi, M. Lauras, P. Couget and V. Chapurlat (2008): A Metamodel and its Ontology to Guide Crisis Characterization and its Collaborative Management, *Proceedings of the 5th International ISCRAM Conference* Washington, USA.

Beydoun, G., G. Low, B. Henderson-Sellers, H. Mouraditis, J. J. G. Sanz, J. Pavon and C. Gonzales-Perez (2009): FAML: A Generic Metamodel for MAS Development. *IEEE Transactions on Software Engineering,* **35**(6): 841-863.

Beydoun, G., G. Low, H. Mouraditis and B. Henderson-Sellers (2008): A Security-Aware Metamodel For Multi-Agent Systems. *Information and Software Technology,* 51 (5): 832-845.

Brinkkemper, S. (1996): Method Engineering: Engineering of Information Systems Development Methods and Tools. *Information and Software Technology,* 38 (4): 275-280.

Doherty, M. (2004): An Emergency Management Model for Home Health Care Organizations. *Home Health Care Management Practice,* 16 (5): 374-382.

Gao, S. and D. Xu (2010): Real-Time Exception Management Decision Model (RTEMDM): Applications in Intelligent Agent-Assisted Decision Support in Logistics and Anti-Money Laundering Domains. *The 44th Hawaii International Conference on System Sciences (HICSS)*, Hawaii.

Heicke, M. (2009). Automated Sequential Composition of Deltas and Related Optimization Operations, Universitat Paderborn, Germany.

Kelly, C. (1998): Simplifying Disasters: Developing a Model For Complex Non-Linear Events, *Australasia and the Pacific Region Conference*, Cairns, Queensland.

Kruchten, P., C. W. K. Monu and M. Sotoodeh (2008): A Conceptual Model Of Disasters Encompassing Multiple Stakeholder Domains. *International Journal of Emergency Management,* **5**(1-2): 25-56.

Manitoba Health Disaster Management Disaster Management Model for the Health Sector: Guideline for Program Development.

Nordstrom, G., J. Sztipanovits, G. Karsai and A. Ledeczi (1999). Metamodeling: Rapid Design and Evolution of Domain-Specific Modeling Environments, Vanderbilt University**:** 156.

Object Management Group (OMG) Model Driven Architecture (MDA) Guide.

Russo, E. E. R., A. B. Raposo, M. Gattass and T. Fernando A Metamodel for Configuring Collaborative Virtual Workspaces: Application in Disaster Management of Oil & Gas Offshore Structures.

Shaluf, I. M. (2008): Technological Disaster Stages and Management. *Journal of Disaster Prevention and Management,* **17**(1): 114-26.

Stahl, T., M. Voelter and K. Czarnecki (2005). *Model-Driven Software Engineering, Technology, Engineering, Management*, John-Wiley & Sons Ltd.

Tierney, K. J., M. K. Lindell and R. W. Perry (2001). *Facing Unexpected Disaster Preparedness and Response in the United States*. Washington DC, Joseph Henry Press.

W3C Incubator Group Emergency Information Interoperability Frameworks. *http://www.w3.org/2005/Incubator/eiif/XGR-Framework-20090806/#ack*.

Weilkiens, T., Ed. (2008). Systems Engineering with SysML/UML, Morgan Kaufmann Publishers Inc.