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An Emerging Decision Support Systems Technology for Disastrous Actions Management

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1. Introduction

Climate disaster and catastrophic incidents create emergency problems that need urgent responses by authorities. To protect human communities and human systems from the impact of disasters, rescue teams and decision makers both from government and non-government agencies need to work closely in a systematic manner. Information collected from different sensors and sources must be shared at different decision making levels. However, Government policy and decision makers at various levels lack appropriate technology needed to assist for decision support that could help them work within their context effectively. Research addressing such a context specific decision support issue for managing and fostering the possible impacts on affecting human communities and taking required actions has to date been limited. An IT based solution integrating new technological provisions can have potential benefit for such problem situations in providing good coordination in decision making for authorities.

The purpose of the chapter is to introduce a conceptual approach of emerging decision support systems (DSS) development in enhancing contextual support in decision making. We analyse the requirements of outlining a technological solution model for addressing disaster management problem situations in which decision makers at different levels can have the information support to respond effectively.

The chapter will be organised in the following way. The next section will provide an overview of the issues in such a DSS solution design for disaster emergency decision making. The following section will describe different DSS technologies and their purposes. The fourth section will include different disaster management aspects considered by previous studies. The section following will describe the proposed DSS model that may have application for decision makers. Section six will present a discussion on the delimitations of the proposed approach in the chapter and finally the outline further research directions will be discussed.

2. Problem background

Traditional DSS models have had limited success supporting decision makers in their problem specific situations for disaster management. Specially, for enabling decision makers' context specific reflection, a decision support framework is required for different stakeholders. Technological provisions for on-site or remote access solution concepts are not new in the use of DSS applications. Although some existing DSS solutions integrate GIS provisions, they lack appropriate process that are required to address concurrent data capturing for decision making and relevant decision sharing in users' context. Buzolic, Mladineo, and Knezic (2002) developed a DSS solution for disaster communications through decision processes in the phases of preparation, prevention and planning of a protection system from natural and other catastrophes, as well as in phases throughout interventions during an emergency situation in the telecommunications part. The DSS model is based on a GIS that only capture location specific necessary data. Using a combination of GIS and multi-criteria DSS approach, according to natural catastrophes such as floods, earthquakes, storms, and bushfires, data regarding the vulnerability of the telecommunications system are generated (Buzolic et al. 2002) in the system model. Similarly, Mirfenderesk (2009) described a DSS designed for mainly to assist in a post-disaster situation. However, this DSS model is used traditional technique for pre-disaster flood emergency planning. As a post-disaster measure it can identify vulnerable populations and assist in the evacuation of those at risk (Mirfenderesk, 2009). Rodríguez, Vitoriano and Montero (2009) developed a DSS for aiding the Humanitarian NGOs concerning the response to natural disasters. This DSS has been developed avoiding sophisticated methodologies that may exceed the infrastructural requirements and constraints of emergency management by NGOs. The used method is not technically novel enough to capture decision makers' context. A relatively simple two-level knowledge methodology is utilised in this approach that allows damage assessment of multiple disaster scenarios (Rodríguez et al. 2009). Apart from these DSS approaches, there some disaster management solution have been developed such as MIKE 11 (Designed by Danish Hydraulic Institute) (Kjelds and Müller, 2008) and SoKNOS (Service-Oriented ArchiteCtures Supporting Networks of Public Security--a service oriented architecture based solution design by the German federal government) (SoKNOS, 2011), but they are still in the embryonic or conception stage of design. None addresses the technical requirements of using business intelligence techniques. Therefore issues remain in designing a relevant decision process with support for policy making and operational levels for disaster impact assessments to meet emergency requirements for the safety of humans and other living beings in emergencies.

Drawing upon the above, in the proposed DSS solution, the architecture comprises several technological layers. The first layer collects disaster information from a range of different sensors or sources. This collected information is then processed through a business analytics method (Davenport and Harris, 2007) before storage in knowledge repositories. In the second layer, analysed results with context details are stored in knowledge repositories with their enhanced semantics. The *Protégé* based knowledge framework (Gennari et al. 2003) is employed for knowledge codifications through a controlled vocabulary principle. Finally, the third layer (called data fostering unit) handles the codified knowledge through different decision making policies or rules (for example, rules based decision making- Miah, Kerr and Gammack, 2009) in various decision making levels. Figure 1 illustrates more detail descriptions.

The digital eco-systems research paradigm provides a powerful and broad methodological foundation for such a DSS solution design for addressing the information needs of different stakeholders. A digital ecosystem enables a platform that facilitates self organizing digital system solutions aimed at creating a digital environment for stakeholders in organizations

(Louarn, 2007). This paradigm supports development of emerging technologies for knowledge interactions between software solutions and users (Miah, 2009). Under this framework, an appropriate perspective of socio-materiality is identified for solution design; in which decision maker's social and material characteristics (e.g. organisational policy, rules and management principles) within the changing context can be captured analytically. The fundamental nature of the socio-material practice perspective is important to capture, including themutually constituted view of the stakeholders/decision makers in their own work context (Wagner, Newell and Piccoli, 2010). In this sense, the DSS structures and internal processes for examples the analytics rules and routines associated with a best practice configuration can be outlined as different decision makers draw upon in their situated practices (Wagner et al. 2010; Orlikowski and Scott, 2008). Given the focus of this study upon understanding how the material aspects of technology are entangled with the social for obtaining appropriate decision making practices, this perspective is grounded in the notion that what people do is always locally defined and emergent (Orlikowski, 2000). This view offers potential benefits for such a BI technique oriented DSS solution design that will adapt to various policy and decision making context.

3. Emerging technologies of disaster DSS

DSS based applications are well- known and extensively applied in disaster management. Various technologies are used for instances, in natural disaster management, such as flood control and forescasting, hazard management and pre and post activities management. Table 1 illustrates various DSS design applications in previous studies.

There are many technologies that have been used in DSS application development for the purpose of disaster situation management. Bessis, Asimakopoulou and Xhafa (2011) highlighted potential use of next generation emerging technologies in managing disaster situations. The technologies are namely: *grid computing* (an information sharing solution that allows integrated, collaborative use of distributed computing resources including servers (nodes), networks, databases, and scientific tools managed by multiple organisations); *web services* (an information sharing infrastructure to provide stateless, persistent services and resolves distributed computing issues); *cloud computing* (a service solution that is defined as incorporating virtualisation and utility computing notions as a type of parallel and distributed system); *pervasive computing* (also known as ubiquitous computing, a means to enable resource computation and utilisation in a mobile or environmentally-embedded manner); and *crowd computing* (a service platform and sometimes called 'crowd-sourced' mobile phone data from citizens) (Bessis et al. 2011).Our findings suggest that there are three main approaches that are used for decision support design in different purpose specific disaster managements, namely: integrated dynamic model based, GIS based and cloud computing based approaches.

Asghar et al. (2006) described a dynamic integrated model for disaster management from their previous study on a single DSS design. The model handles specific decision-making needs through the use of combining more than one model. Literature in Asghar et al. (2006) suggested that different DSS systems are designed for various categories of disasters and most of the time DSSs are based on specific models and decision support needs. However, there are different needs of decision support in disaster management in that one single model may not be sufficient to cope with the problem situations (Asghar et al. 2006). Asghar's et al integrated model is decomposed into modular subroutines that are functionally independent in the problem space.

Purpose of decision support solutions	*Descriptions*
Assilzadeha and Mansora (2011) Hazard Decision Support System (HDSS)	HDSS states the scheme, which has to be developed to cater to the requirements of pre, during and post disaster activities. During the events of the disaster, the approach enables user to send and retrieve information as required through the use of handheld devices such as mobile and PDAs. In addition, users can obtain urgent messages or alerts transmitted on their mobile phones in the form of SMS.
TELEFLEUR (Cioca and Cioca, 2010) TELEmatics-assisted handling of FLood Emergencies	The solution is developed for the prevention and management of floods, which combines telematic technologies with advanced meteorological and hydrological forecasting encapsulated in a decision support system.
GIS Based DSS (Buzolic, Mladineo & Knezic, 2009)	The DSS is developed for disaster communications through decision processes in the phases of preparation, prevention, and planning of a protection system from natural and other catastrophes, as well as interventions during an emergency situation. The model captures the necessary location-specific data.
Post and pre disaster DSS (Mirfenderesk, 2009)	The decision system is designed to assist mainly in the post-and pre disaster situation. As a post-disaster measure it can identify a vulnerable population and assist in the evacuation of the population at risk.
Integrated DSS (Asghar, Alahakoon and Churilov, 2006)	The DSS approach is described as dynamic integrated model for disaster management decision support. The model is created on the basis of a given disaster scenario and described the main components of the framework and usefulness of the proposed integrated model. The intelligent technique is used to select the group of subroutines to create the integrated model.

Table 1. Different purpose and technologies used for disaster management DSS development

Gupta (2011) described various stages involved in the preparation of GIS based DSS for disaster management in India. The solution includes the development of an integrated geo-database that consists of various thematic maps, demographic data, socio-economic data and infrastructural facilities at remote level (Gupta, 2011). Gupta's approach uses a menu driven system that is used by administrators who may not have in-depth knowledge of working in GIS. Adityam and Sarkar (1998) also describe a GIS-based DSS for Indian cities affected by cyclones. However, the approach is focused on disaster preparedness and planning through the use of GIS technologies.

The term "cloud computing" has become popular due to its contribution to shared computing applications. Fitzgerald and Dennis (2010) described cloud based design as a "*circuit-switched service architecture*" that is easier to implement for organisations because *"they move the burden of network design and management inside the cloud"* (p. 297). As such, cloud computing provision has been used as a modern architecture of shared computing services. When Amazon.com provided web-based utility services, many service providers became interested in utilising the cloud computing platform for launching new services that met their client group demands through its stable infrastructure (Santos, Gummadi & Rodrigues, 2009). Many studies found cloud computing useful in public safety and disaster management applications. In theory, the approach supports a convergence of interactions and decision making in a broader community perspective.

4. Disaster management aspects

In disaster situations involves a number of entities such as disaster management authorities, teams and individuals from more than one location that are geographically distributed. The entities can be for example medical teams, rescue services, police, civil protection, fire, health and safety professionals, and ambulance services that will be required to communicate, cooperate and collaborate – in real time – in order to take appropriate decisions and actions (Bessin et al. 2011, Graves, 2004; Often et al., 2004). This implies that decision making for such combined action taking is rather multifarious due to diverse information processing from different sources. Carle et al. (2004) suggest that *"there are frequent quotes regarding the lack and inconsistent views of information shared in emergency operations"* (Bessin et al. 2011 p. 77). Carle et al. (2004) also reported that information exchange during an emergency situation is very important and can be very diverse and complex and at analysing information is very important, yet none of the current technologies support such needs.

Disaster managers play important roles in disaster situations. Asimakopoulou and Bessis (2010) and Bessis et al. (2010) note that disaster managers are required to identify the site of people and evaluate their present and projected impacts, because there is no real benefit in sending rescue team to a place if there is no one actually present. This implies that disaster managers need analysed information to make such a quick decision in an appropriate way. Because, it is important to urgently send the rescue team to a place where there is a great risk of someone or many injured. It is straightforward to construct many plausible scenarios where knowledge can be collected from various emerging technologies to the benefit of the disaster managers and the society. In other words, access to shared information regarding the number, whereabouts and health of people in an area struck by a disaster will significantly enhance the ability of disaster managers to respond timely to the reality of the situation. The aforementioned challenges are so vast and multifaceted that it is clearly insufficient to address all of them here.

A framework for analysing disaster management activities is outlined by Wallace & De Balogh, (1985). The proposed framework uses pre and post event based activities for identifying scope of DSS development. The approach can be useful to guide the implementation of DSS technologies for specific purpose.

As mentioned previously, a service oriented architecture based solution in the public security sector called SoKNOS (SoKNOS, 2011) has been developed, in which different technological and user oriented objectives will be investigated such as machine-readable semantics, user-friendly workplace, highly-reliable system behavior and integral data processing. Another objective is machine readable semantics to provide relevant services to user contexts using appropriate machine readable coding in developed technology. Further objective is the user-friendly workplace, which concerns fulfilling decision makers' desires through technological features. This aspect relates to how the technology will accommodate current user's problem scenario and information flow appropriate to particular situation. To

Type	*Operation control Timeframe = 6 months*	*Management control Timeframe = 6months to 1 years*	*Strategic planning Timeframe = more than a year*
Structured tasks	Pre-event such as Inspection Inventory of resources	Pre-event such as Development of resources Development of reporting formats	Pre-event such as securing budgetary and legislative support for programs
Structured tasks	Post-event such as Damage assessment Epidemiological surveillance	Post-event such as Treatment of injured Deployment of relief forces	Post-event such as allocation of scarce resources Development of zoning and regulatory standards
Semi structured tasks	Pre-event such as warning and alerting Meteorological data assessment	Pre-event such as Development of procedures for conducting post event damage and loss assessment	Pre-event as such enforcement of zoning and similar standards Tests and exercises
Semi structured tasks	Post event such as Notification of responsible officials Evacuation plan implementation	Post event such as Declaration of state of emergency Set up triage/reception centers	Post event such as administration of disaster relief Determination of priorities of needs
Unstructured tasks	Pre-event such as Unanticipated personnel problems Exacerbating events	Pre-event such as Replacement for loss of key Personnel and equipment	Pre-event Actions to be considered in legal of unexpected findings (e.g. geological fault under a nuclear facility)
Unstructured tasks	Post-event such as equipment malfunction Impacts not foreseen	Post-event such as Coping with secondary effects such as epidemics Search and rescue	Post-event such as Decision to relocate populace Major recovery expenditures

Table 2. Activities under disaster management scenario
(adapted from Wallace & De Balogh, 1985)

achieve the objective of developing reliable system behaviour, the technology should demonstrate robust behaviour that helps achieve reliability through its innovative mechanisms. The integral data processing requires the technical development that combines internal and external data readable to decision makers. These objectives are useful in motivating further technology development for disaster management; however, this project is still in its conceptual stage. From this perspective this study adopts the principle "*technology should demonstrate robust behaviour that helps achieve reliability*" to outline a business intelligence technique based DSS model in this chapter that guides a conceptual solution design.

5. Proposed DSS framework

Recent research in business intelligence (BI) suggest that the approach can be supportive for any decision support solutions including its underlying architectures, tools, databases, applications, and methodologies (Raisinghani 2004). Negash (2004) provides a definition of BI as follows:

"combine data gathering, data storage, and knowledge management with analytical tools to present complex internal and competitive information to planners and decision makers"

Turban et al. (2008) describes BI's main purposes as enabling interactive and easy access to data, its manipulation and transformation to provide business managers the required decision support. This implies that the approach can add value to decision makers in a disaster management situation where they need to process and transform diverse data. As such, the BI approach is now widely adopted in the world of application design for decision making aid (Watson and Wixom 2007). Drawing from this, this study outlines a BI based conceptual solution in which diverse data are retrieved and manipulated through an analytics filter at the initial stage. Figure 1 illustrates the proposed solution model. The first layer ranges from data sources to knowledge repository; the second from knowledge repository to data fostering; and the third extends from data fostering unit to user group access. At the first layer, the aim is to create meaningful data for storing in the knowledge repository.

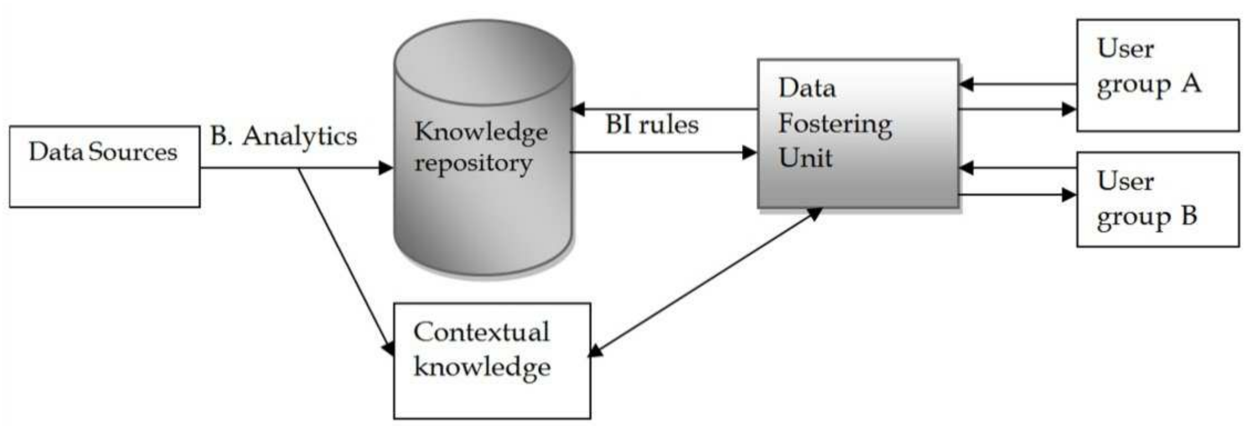

Fig. 1. Conceptual solution model of the proposed decision support systems

After storing the data in the knowledge repository, using an ontology model defined in protégé II (Gennari et al. 2003), the data fostering unit (second layer) use BI rules which will be generated from contextual knowledge to transform the meaningful information to different decision makers at the third layer. It is suggested that BI heavily relies on advanced data collection, extraction, and analysis technologies (Watson and Wixom 2007). In the proposed process, business analytics ensures advanced data collections from a range of data sources with context specific detail knowledge. To extract the data, BI rules ensure appropriate contextual information generation of the stored data to improve decision making. In the data fostering unit, (third layer) the user group can select options relevant to their context, for example by defining parameters for the BI rules. During the events of the disaster, the user is able to send and retrieve information through the use of handheld devices such as mobile and PDA. The data fostering unit can even transmit urgent message and alerts to mobile phones in the form of SMS.

6. Discussion and conclusion

The chapter discussed the potential of a new BI based decision system design to manage disastrous situations. In the context of a decision-support application, the chapter described technologies used in previous applications. The proposed BI based decision system solution used a rule-based approach for ensuring appropriate decision-making through the application of BI both in data storing and retrieving. This initiative reinforces a shift from the traditional DSS application design to a business focused user context specific DSS provision, which allows flexibility and situation specific reflection of real world emergency situations. At the same time, decision makers can actively perform effective decision making, liaise with relevant authorities for sharing data (e.g. relevant climate forecasting, weather conditions) and action-taking on real problems while in the emergency location.

The chapter presented a conceptual solution approach for the target problem area in which decision making needs contextual reflection. The goal was to establish a theoretical foundation for designing and evaluating decision system solution within a real management environment. Outlining the requirement of decision system design the chapter explored a range of DSS techniques and their usage in application areas. It was argued that traditional initiatives are far from a solution that can address situation specific issues and sensitivity of decision makers at different levels.

7. Further research directions

The chapter introduced various DSS applications for disaster management to outline an emergent requirement of context sensitive DSS design. While the findings presented in this chapter are based on a review of previous relevant research, they represent only an early stage analysis of developing a DSS solution in the target application area. Further research will be required for designing a specific knowledge repository using ontology design principle within a real problem scenario that will be capable of working with BI provisions. The interactive users' provisions in such DSS application design can also be a challenge. In this purpose, user specific provisions are required for each user groups to enable improved decision making or action taking through data transition into actionable information. An in-depth study is also required for system integration considering a wide range of BI rules development form 'rules of thumb' (scientific knowledge and practice based understanding) of the emergency situations and to ensure compatibility of the different components within the mobile and wireless operating environment. For acquiring the domain knowledge, further research is required for empirical investigations and which will help outline all of the required 'rules of thumb' in the target area of decision making.

Further to evaluate the outlined DSS technique, a test environment for such solution design will be required for ensuring appropriate information generation according to the different user groups' requirements. This test will also help identify technical difficulties of the proposed solution and various process-oriented challenges associated with user's acceptance and satisfaction.

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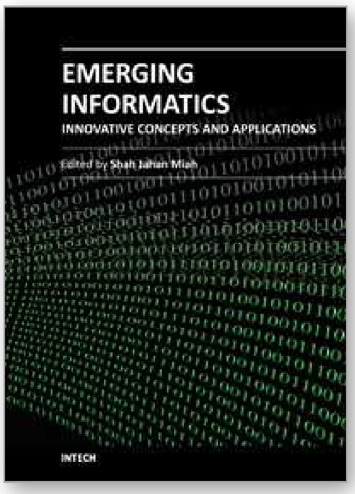

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The book on emerging informatics brings together the new concepts and applications that will help define and outline problem solving methods and features in designing business and human systems. It covers international aspects of information systems design in which many relevant technologies are introduced for the welfare of human and business systems. This initiative can be viewed as an emergent area of informatics that helps better conceptualise and design new world-class solutions. The book provides four flexible sections that accommodate total of fourteen chapters. The section specifies learning contexts in emerging fields. Each chapter presents a clear basis through the problem conception and its applicable technological solutions. I hope this will help further exploration of knowledge in the informatics discipline.