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Integrated community emergency management and awareness system: A knowledge management system for disaster support

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ABSTRACT

The initial start of this paper deals with reviewing the literature on Emergency Management Information Systems (EMIS) and integrating it into a Knowledge Management System (KMS) structures. This leads to the ability to take information seeking tasks in Emergency Management and translate it to a path in Knowledge Management Structure. This was used to develop an ability to compare current time requirements for information via current data-bases and phones with the performance of an integrated Knowledge Management System in 128 emergency managers of the Government of Malaysia via multi-method strategy including survey, interviews and simulation tests. This led to the recognition of the potential of such a system for the country and the initial parameters of a prototype of the first implemented system design. The resulting integrated Community Emergency Management and Awareness Systems (iCEMAS) is a prototype KMS that was developed and tested. This paper seeks to emphasize that a KMS for emergency management must incorporate features that enable role changes and allow people to access changes based on the situational requirement. The paper provides a highly concise overview and results that supplements our systematic review of KMS in Emergency Management in 2013.

1. Introduction

Over the last two decades (1995–2015), disaster losses remain substantial because of increasing frequency of disasters, especially in developing countries. The Global Assessment Report 2015 on Disaster Risk Reduction by the United Nations reports that an average annual loss from disaster such as tsunami, river flooding, cyclone and earthquakes is estimated at USD314 billion for built environment (GAR, 2015). This amount must be set aside by all countries to prepare for future disasters. The occurrence of weather-related disasters has increased by 14% in the last decade, thereby making the number of disasters as 335 per year. Although the number of affected people has decreased from 245 million people in 1995–2004 to 165 million in 2005–2014, the number of deaths has increased from an average of 24,000 per year in 1995–2004 to 36,000 per year in 2005–2014 (CRED, 2015). This shows the increasing trends in vulnerability of the community at risk and the need for an improved resiliency level.

The various initiatives that are being implemented throughout the world indicate the heightened awareness on improving resiliency level. One such initiative by the United Nations is Making Cities Resilient: "My City is Getting Ready" (CRED, 2015). In August 2015, the campaign had 2550 cities as members. The campaign tools, namely the Local Hyogo Framework for Action Monitor, the "10 essentials" and the disaster resilience scorecard, have provided municipalities with the means for a better understanding and managing disaster risk (CRED, 2015). A total population of 700 million people is committed in this campaign. They consist of residents of all cities and local governments. Fifty-four role model cities play essential roles in increasing knowledge sharing among city officials to make cities more resilient (CRED, 2015). However, many developing countries, including Malaysia, continue to struggle in alleviating the resiliency level.

The need for a more resilient community is also felt in Malaysia. Our preliminary interviews with the National Security Council of Malaysia (NSC), the main agency that manages emergency revealed that the country is facing three main challenges. These challenges include (1) poor communication, coordination and collaboration (3Cs) between the council members and its affiliate agencies (2) lack of proper data/information management and (3) limited knowledge sharing and dissemination within the organization (Dorasamy and Raman, 2011). Disaster-prone areas are totally dependent on the government agencies' support.

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Despite extensive programs and initiatives by the government, vulnerable communities are still far from self-awareness on disaster resilience (Dorasamy and Raman, 2011). This naturally results in low resilience level among citizens.

The existence of various stakeholders in emergency management presents a complex set of skills and experiences that create a complex and dynamic environment (Jennex, 2008, 2012). The emergency management stakeholders in Malaysia include government agencies for health, agriculture, civil, environment and chemical; rescue teams, which involve police, fire and rescue department, army, volunteers, public service department, hospitals and Special Malaysia Disaster Assistance and Rescue Team (SMART); recovery teams, which involve road works, local recovery rescue team, energy and electricity board, telecommunication, irrigation and meteorology department; welfare teams, which include welfare department, non-government organizations (NGO), and health department; international teams involving the United Nations, experts in medical, psychology, disaster, technology, volunteers, and scientific researchers; NGOs such as the Red Cross and religious-based associations; vulnerable communities, special interest groups, and victims; and medias team and policy makers. This complexity leads to difficulty in making life-saving decisions. Knowledge from past experiences is not systematically collected and readily available for future retrieval.

Interest in knowledge management (KM) and knowledge management systems (KMS) for emergency management (EM) has increased because of the alarming occurrences of disasters worldwide, the existence of complex structure of stakeholders in the disaster domain, and the low resiliency level among citizens. The use of KM and KMS functions for EM is supported and recommended by existing literature. KMS could play an important role in improving the speed and quality of response actions (Murphy and Jennex, 2006; Raman et al., 2006). Future emergency management information systems (EMIS) should incorporate KM considerations because KMS has the ability to handle both explicit and tacit knowledge (Borkulo et al., 2005). The present study postulate that this is a KM problem and that an effective KMS is necessary. Hence, a well-designed KMS could support the national EM generally and community resiliency specifically. KMS can be used to capture and reuse EM knowledge by applying knowledge from past experiences to support decision-making in EM (Jennex, 2005, 2008). Effective decision-making can lead to organizational efficiency and effectiveness.

Evidently, information systems (IS) can ease prominent EM issues. The EM issues include the lack of integrated systems for 3Cs (Catarci et al., 2011; Cao & Zhou, 2008), as well as lack of free flow of information across various stakeholders (Dorasamy et al., 2014; McEntire, 2012; Turoff et al., 2011). Scholars have affirmed that IS could provide real-time accessibility, visibility and availability of information and knowledge (Turoff, 2012; Bui and Sebastian, 2011; Seneviratne et al., 2010). As a result, increase in both individual and organizational responses to turbulence and discontinuities will ensure high resiliency (Bhamra et al., 2011).

One common trend in IS literature involves emergency management information systems. System designers seem to have placed greater emphasis on system functions and features that are model-based or based on technical requirements rather than situational (Shen et al., 2012; French et al., 2009; Borkulo et al., 2005; French and Niculae, 2004; Turoff et al., 2004). Disaster management demands the communication of life-saving information or knowledge, coordination among different and possibly unknown roles and actors as well as collaboration between different groups through socialization (Plotnick and Turoff, 2011; Samarajiva, 2005; Turoff et al., 2004; Turoff et al., 2011). These demands are uncertain because disasters are unique, complex, unpredictable, and dynamic by nature (Ashish et al., 2008; Raman et al., 2006). Thus, developing an EMIS based on data analysis and models alone may not fit complex situations such as disasters (French and Niculae, 2004).

Given that, disaster situations are often unique and demand greater coordination in multi-party context, time constraint decision-making, and changes in roles and responsibilities, this paper proposes that success of an IS for emergency requires additional situational qualities. Situational qualities includes environmental complexity, rigidity in responding to threat, dynamic response, situational awareness, changes in roles and responsibilities, cognitive absorption, as well as agility and discipline. Situational qualities will provide vital design considerations for effective emergency management information systems in terms of lesser time taken for emergency decision-making.

The proposed prototype was named iCEMAS (Integrated Community Emergency Management and Awareness System) with two main sub components, namely MySedia (a portal for community) and CEMAS (the dashboard containing database functions, communication tools and disaster knowledge bank) and implemented in the NSC. The system was simulated, tested and evaluated to ascertain its effectiveness to support EM in the NSC toward improving the overall resiliency level in the nation. The kernel theory used for this research is the KMS Success Model by Jennex and Olfman (2006). The model is an extension of the IS success model of Delone and McLean (2003). This research attempts to solve the puzzle of designing a KMS for EM, thereby ensuring that IS could effectively support unique and complex situations, thus improve disaster resilience.

Against this backdrop, the present paper has the following objectives:

(1) To develop a model that explains and guides an effective design considerations for KMS success to support EM;
(2) To develop and implement a web-based KMS prototype to address the 3Cs, information visibility, as well as information/knowledge sharing and dissemination challenges that face the NSC and community in relation to its EM efforts toward improving disaster resilience.

These objectives required the researchers' direct participation and involvement with NSC.[1] Therefore, an action research method was used as the underlying methodology to conduct the study. Specifically, canonical action research (CAR) was chosen and was used to guide the research. By linking situational qualities to the net benefit of a well-designed KMS for EM, this work is expected to contribute to research on applied-KMS[2] for EM and disaster resilience. This work responds to the call to move beyond technocentric systems and include construct related to socio-technical components (French & Niculae, 2004). The importance of time saving by using EMIS during time-constrained situations is underscored in prior research. By developing a system with strong underlying theories that guide the design consideration which in turn can lead to greater time saving for emergency managers, it is expected to contribute to the understanding of interventions to foster KMS success in general and KMS for EM in particular. In 2013, a state of the art review of KMS in EM was presented and this paper provides a concise overview with some details of new review material on knowledge systems (Dorasamy et al., 2013). Finally, this work will contribute to our understanding on how a well-designed system that incorporates situational quality in KMS for EM will result in improved disaster resiliency of community and emergency managers, especially in developing countries that are constantly facing challenges from disaster occurrences, as well as time saving during critical decision-making.

[1] National Security Council is the main agency that manages all the activities related to emergency management.

[2] Applied KMS refers to actual system that was built and applied in the real situation to solve the problem studied.

2. Theory

This section first presents a discussion and justification of the constructs in the model. The model is then mapped toward guiding design considerations for the proposed system.

2.1. Knowledge management system

In the Information System perspective, KMS refers to the effective tool for enabling the KM processes. In this context, KMS is the key enabler of KM and is applied in nature. Many papers define KMS as IT-based systems developed to support and enhance organizational process such as knowledge creation, storage/retrieval, transfer, and application (Turban et al., 2008; O'Brien et al., 2002; Malhotra and Galleta, 2003; Alavi and Leidner, 2001). IT can enhance the interaction of individual, group, organizational, and inter-organizational knowledge (Hedlund, 1994; Nonaka and Takeuchi, 1995; Noordin et al., 2013), as well as support KM and organizational learning (Bennet and Tomblin, 2006; Jennex, 2012).

Gupta et al. (2004) presented seven categories of tools that can comprise a KMS, including knowledge-based systems, document management systems, semantic networks, object-oriented and relational database, decision support systems (DSS), expert systems, as well as simulation tools (Lindgren et al., 2004). Any one or combination of these tools can be designed as effective KMS. DSS, simulation tools, database, groupware and intranet are among the tools of choice for many researchers. For example, Holsapple and Whinston (2001), as well as Alavi and Joachimsthaler (1992) used DSS as the overall representation of their KMS. Stenmark and Lindgren (2008) and O'Brien et al. (2002) used database concepts to form a KMS. Alavi and Liedner (1999, p.22) concluded that "an integrated and integrative technology architecture is a key driver for KMS. No one single dominant technological tools or product for KMS emerged in our survey".

2.2. Constructs for KMS success

The KMS Success Model by Jennex and Olfman (2006) was used as the theoretical foundation in guidance to design a prototype using an open source platform. The model presents system, knowledge, and service qualities as three main dimensions that influence user satisfaction and intent to use toward impacting the net benefit of a KMS. Jennex and Olfman (2006) developed this model based on DeLone and McLean's Information Systems success model (DeLone and McLean, 2003). The model transitioned from an information to a knowledge-based system. Knowledge accounts for both explicit and tacit types of knowledge that are expertise-oriented (Uday et al., 2006). This model shows the success factors of KMS by changing the names of information quality dimension to knowledge quality and by adding new constructs to this success model. The model has three main quality dimensions, namely, system, knowledge, and service qualities. The success factors that influence two other factors are intent to use and user satisfaction. These two factors finally influence the net benefits of KMS implementation to individuals and organizations. Jennex and Olfman changed the information dimension to knowledge dimension. They likewise added three constructs to represent each of the dimensions. System quality is measured by technological resources, KM level and KM form. Knowledge quality is measured by KM strategy/process, richness, and linkages. Service quality is measured by management support, IS KM-service quality and user KM-service quality. A KMS can be effectively designed to support groups in emergency management particularly for a disaster response phase that is complex, dynamic, and stressful in nature. Literature on applied and conceptual EMIS discussed these factors. The factors are described briefly as below:

2.2.1. System quality

System quality refers to "how well the KMS performs the functions of knowledge creation, storage/retrieval, transfer, and application; how much of the knowledge is represented in the computerized portion of the OM (organizational memory); and the KM infrastructure" (Jennex and Olfman, 2006, p.40). In the EM environment, a KMS should possess the following system characteristics: usability, availability, reliability, adaptability, and response time. In terms of system quality (SQ) and KMS for emergency managers, the system should consider the existing software, hardware, network, database, platform, knowledge input forms, various knowledge representations, knowledge retrieval time expected, level of usability expected, and KMS functions at different levels such as district and state level.

2.2.2. Knowledge quality

Knowledge quality (KQ) refers to the extent to which "KM processes and an enterprise-wide knowledge infrastructure, incorporating KM processes into regular work practices, and that knowledge needs were different for users of different levels, were key issues in order to determine and implement what is the right knowledge for KM to capture." (Jennex and Olfman, 2006, pg. 40). KMS success for emergency managers involves how the system can benefit the productivity of emergency managers. Therefore, the KMS can use various interface options, which provide an interactive and easy-to-use capabilities for knowledge storage, transfer, and dissemination processes.

2.2.3. Service quality

Service quality refers to whether "the organization has adequate service support from management, user organizations, and the IS organization to ensure that KM has adequate support in order for users to utilize KM effectively" (Jennex and Olfman, 2006, p.42). In ascertaining the success of a KMS for emergency managers, development and implementation can focus on existing system capabilities and service quality (SerQ) required by the KM team, such as responsiveness, effectiveness, and competence levels. Emergency managers with effective IS team service quality and management support will improve the success of KMS for EM.

2.2.4. Intent to use

Intent to use measures the user perceptions of KM benefits. These perceptions depend on whether users positively assume that using a KMS can benefit their productivity despite the unique disaster situation, such as stressful and time-constrained decision-making.

2.2.5. User satisfaction

User satisfaction refers to the desire to use KMS depending on whether users perceive that KMS can potentially satisfy their needs in processing information during complex situations, such as disasters (DeLone and McLean, 2003; Jennex and Olfman, 2006).

2.3. Situational dimension

Managing disasters demand the communication of life-saving information or knowledge, coordination among different and possibly unknown roles and actors as well as collaboration between different groups through socialization (Plotnick and Turoff, 2011; Samarajiva, 2005; Turoff et al., 2004, 2011). These demands are uncertain because disasters are unique, complex, unpredictable, and dynamic by nature (Raman et al., 2006). Thus, developing an EMIS based on data analysis and models alone may not fit complex situations such as disasters (French and Niculae, 2004).

The KMS success model is useful in the broad organizational context of KMS implementation. However, the model requires modification to match the unique nature of emergency situations. The present study supports the argument of French and Niculae (2004) who indicated that socio-technical IS are more appropriate in an emergency situation compared with a purely model- and technical-based approach. Consequently, the present study proposed that the assessment of KMS success within a disaster environment should include the examination of the situational dimension. The situational approach in complex disaster situations guides the identification of suitable constructs for testing the model. Furthermore, KMS in EM can be classified as a socio-technical system; a system developed and implemented to support the relevant knowledge required in a given social structure or organizational context. This system requires the interaction between technology and people in a given emergency (Burnell et al., 2004; Iyer et al., 2009; Jennex, 2008; Jennex and Olfman, 2006; Kostman, 2004; Turoff, 1972; Van Kirk, 2004).

Each unique situation in the situational approach demands different types of response and decision-making. Hersey and Blanchard (1969) developed this approach based on the 3D management style theory (Reddin, 1967). In this context, a situation is a "set of values and attitudes with which the individual or group has to deal in a process of activity and with regard to which this activity is planned and its results appreciated. Every concrete activity is the solution of a situation." Situational dimension was included because a disaster situation is unique in nature. Technological support for disasters may exist in various forms or tools such as decision support systems (DSS), group communication systems, intranet, expert systems, or web-based applications. However, the success of such systems depends on various situational qualities, which include unique characteristics of disaster contexts (Bui and Sebastian, 2011). Thus, the present study suggests that the situational quality may influence the emergency manager to adapt to the unique scenario at hand.

Fig. 1 shows that decision-making occurs in four different situations or domains called the "known," "knowable," "complex," and "chaotic." Cause and effect can be predicted in the known and knowable domains. However, information in the complex and chaotic domains is almost impossible to predict (Borkulo et al., 2005; French & Niculae, 2004; Snowden, 2002). According to Snowden (2002) as well as French and Niculae (2004), causes and effects always change and are closely intertwined. Similarly, in a complex domain such as a disaster situation, the causes and effects are often unpredictable because of the unique disaster attributes such as uncertainty, lack of communication and coordination, stress, as well as unforeseen effects. Therefore, the model below can assume a KM perspective, in the context of EM.

A KMS can be effectively designed to support groups in planning and responding to complex, dynamic, and stressful situations such as disasters. Literature on applied and conceptual EMIS discussed these factors. Situational quality (SitQ) is a suitable factor for EM, because emergency situations are unique, unlike common business organizations. The unique characteristics of EM situations include scarce resources; time-pressured decisions; absence of critical information; stressful, dynamic, and ad-hoc environments; complexity; and the necessity of decision-

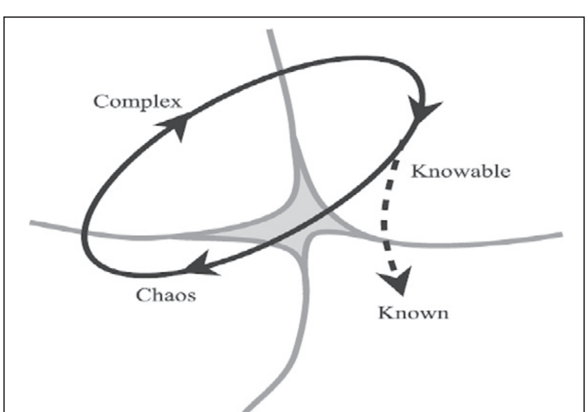


Fig. 1. Cynefin: knowledge flows (Snowden, 2002, p.108; French and Niculae, 2004).

making processes based on sense-making methods. SitQ refers to a set of unique characteristics of situations that demand different types of response, values and attitudes that the individual or group has to address in a knowledge process of activity. Based on previous literature and the unique characteristics of disaster situations as discussed in the earlier section, seven measures of SitQ, as described below.

2.3.1. SitQ1: complexity of environment

Complexity of environment (CE) refers to an environment that is uncertain, stressful, under time pressure, has unique problems, unpredictable, unexpected, and involves multi-party elements. This variable has unique and unexpected problems that may cause difficulty in accessing IS. CE not only includes external environments that are extreme, chaotic and intense, but also includes the complexity of system that represents the information and knowledge. Prasanna et al. (2011) echoed that a system that is complex would present poor internal representation, causing misinterpretation of information. Therefore, a KMS for EM should not have too many layers of information or menus (Prasanna et al., 2011) that would slow down the decision-making process. Less complexity will improve quick learning and reduce trainings (Turoff et al., 2004, 2008, 2011; Prasanna et al., 2011; Jennex, 2007; Raman et al., 2006).

2.3.2. SitQ2: situational awareness

Situational awareness (SA) refers to "the perception and interpretation of environmental elements in the context of time and space, and the projection of what is likely to occur in order to define an appropriate action" (Bui and Sebastian, 2011, p.163, Burstein et al., 2011, Endsley and Garland, 2000). SA is typically based on the following:

a. "Prior knowledge and understanding of the decision-maker about the problem at hand helps to identify the problem and its possible solutions" (Bui and Sebastian, 2011, p.3, Endsley and Garland, 2000)
b. "Ability to scan the environment to formulate a context-sensitive approach to problem solving" (Bui and Sebastian, 2011, p.3, Endsley and Garland, 2000)

Many studies support the SA factor (Ashish et al., 2008; Dorasamy et al., 2012; Gibbins et al., 2004; Harrald and Jefferson, 2007; Madey et al., 2007). Ashish et al. (2008) described SA as the availability of information on people, their vulnerabilities, location, and demographics that are important for an effective use of a system for EM. Yang et al. (2009) described that SA is an important factor in designing user interfaces that would influence user ability to perceive, comprehend, and use the needed information. Carver and Turoff (2007) shared a common perception on SA. They believed that a system with SA is essential to first responders and incident commanders in emergency response. To be aware of the real situation is vital in managing complex events such as disaster situation. Responders need access to the life-saving knowledge that may spell the difference in a life and death situation.

The following SA characteristics were derived from other literature and are thus possible measures of this variable. SA includes information on vulnerable people such as their demographic information, resources (food, water and shelter), progression of the events and activities (evacuation process), and a multi-party group who shares information across a distributed organizational network (Seppänen et al., 2013; Ashish et al., 2008; Caralli et al., 2004; Rockhart and Bullen, 1981). Madey et al. (2007) designed a prototype wireless phone-based emergency response system that provides enhanced SA for managers in emergency operation centers during disaster events. Madey et al. (2007) affirmed that a high level of SA is a prerequisite for the effective performance of emergency managers. Harrald and Jefferson (2007) further enhanced this factor by developing a model of shared SA in emergency mitigation and response. They indicated that information needs change during disaster situations, as not all actors involved in EM require the same information. Hence, they recommended that an information system developed to support EM must enhance shared SA, without impeding organizational agility.

2.3.3. SitQ3: cognitive absorption

Cognitive absorption (CA) refers to a psychological state of a person who is deeply involved in an activity and has the ability to remember, think, and reason with external aids (Agarwal and Karahanna, 2000). Given that EM activities are stressful, socio-cognitive characteristics are important criteria in testing a successful IS, particularly in the context of emergency situations that involve stress (Kassam et al., 2009; Paton et al., 2010; Sattler, 2000). In particular, this study focused on CA in terms of absorption of KMS use for EM. Prasanna et al. (2011) who developed a prototype system for fire fighters, and testified that a stressful work situation likely results in further decision-making errors and mistakes. Thus, they concluded that a system that does not consider stressors could lead to inappropriate system use. On the other hand, a system that has support system and proper design of user interface may reduce work-related stressors.

Past literature indicates that cognitive absorption and cognitive burden is inversely related (Plotnick & Turoff, 2011; Agarwal and Karahanna, 2000). A person with less cognitive burden will be able to quickly absorb information. Any effective KMS "should provide its user with a right representation of artifacts, right set of operational tools, and means to use external data sources to support his/her mental ability to recall and manipulate information." (Bui and Sebastian, 2011, p.3; Plotnick and Turoff, 2011) KMS with the ability to provide **involvement in activities**, such as responding to threat and enhancing **creativity**, would increase CA and lessen threat rigidity (Plotnick and Turoff, 2011). Agarwal and Karahanna (2000) found that in software use, individuals who are cognitively absorbed would be able to effectively "muddle through". KMS can increase CA with features that allow users to effectively **muddle through and make sense** of the reality they face. Saade and Bahli (2005) supported this proposition in their holistic research, which produced a positive effect on the perceived usefulness of system. They mentioned specific characteristics that include focused **immersion**, being totally immersed in whatever task carried out, as well as **enjoyment**, which refers to system features with the ability to heighten enjoyment. The study found that the CA has a positive effect on the perceived usefulness of an Internet-based learning system. Hence, a KMS-EM system design should consider the CA factor.

2.3.4. SitQ4: discipline and agility

Discipline refers to well-organized memories, historical data, and experience (Boehm and Turner, 2004; Harrald, 2006), whereas agility refers to application of memory and history within the context of complex environment to tackle the unexpected situation (Harrald, 2006). Boehm and Turner (2004, p.1) affirmed that discipline triggers agility. In the context of KMS for EM, a system that has organized memories of disasters, experts, assets, drills, standard operating procedures and reports, would enhance the inflow of tacit knowledge to face the unexpected situation, improvise decision-making and adjust to changing needs.

Barry Boehm and Richard Turner in 'Balancing Agility and Discipline: A Guide for the Perplexed' (2004) stated that agility improves satisfaction and expectation of users despite the complexity of situation by allowing a certain level of control and change management. Hence, a KMS-EM system design should consider the discipline and agility factor.

2.3.5. SitQ5: roles

One notable component of situational quality is roles. Roles were suggested by Turoff et al. (2004, 2011) as an important feature of any emergency system. A KMS for EM must incorporate features that enable role changes and allow people to access changes based on the situational requirement. The ability to change roles and responsibilities is crucial in the situational dimension for the facilitation of dynamic roles and formation of teams. Turoff et al. (2004) suggested 12 fundamental roles. Research in embedding roles in KMS is limited. This point was emphasized in our 2013 paper with a more detailed listing of roles and their occurrence in EMIS papers (Dorasamy et al., 2013). In this study, we highlight the role alignment of 12 fundamental roles, as called for by Turoff et al. (2004), in the context of creating dynamic systems in aid of emergency management efforts. The researcher recommends detailed research on roles as an integrated element, particularly in the types of tools developed and tested as well as types of works done for system mapping to roles that emergency responders require in relation to system use. The prototype was designed to include at least 10 roles in the KMS aimed to support EM: 1) report and update situation; 2) analyze situation; 3) edit, organize and summarize the information; 4) maintain resources; 5) acquire more or new resources; 6) alert all with a need to know; 7) oversight review, consult, and advise; 8) assign roles and responsibilities when needed; 9) coordinate among different resource areas; and 10) priority and strategy setting.

The roles were incorporated in the EMISARI designed to facilitate effective communication between people involved in monitoring the Wage Price Freeze situation in the United States in 1971 (Turoff et al., 2004, 2008; Hiltz & Turoff, 1978). Roles may differ based on situations. As disaster situations are unique, any system designed for EM must be flexible and users should be able to define, redefine or adopt new roles. This is referred to as the dynamic forming of teams. The person who administers the KMS should be given the authority to assign roles to any member of the system based on specific responsibility at that time. These roles must be supported with relevant functionalities and priorities within the KMS (Turoff et al., 2004). Hence, a KMS-EM system design should consider the roles factor.

2.3.6. SitQ6: dynamic response

Dynamic response refers to the ability of elements within disaster situations to act dynamically to response to the critical needs. Literature has listed the following characteristics to represent dynamic response. A working team that regularly meets, communicates, shares experiences, and builds trust is important to ensure dynamic response during disaster situations (Turoff et al., 2004). Regular test refers to drills, training, simulations, and exercises related to disaster situations. Well-trained and experienced teams, communication systems (Turoff et al., 2004), collectives of people and lessons learned will improve dynamic response. Hence, a KMS-EM system design should consider the dynamic response factor.

2.3.7. SitQ7: rigidity in response

Response rigidity refers to a "situation where decision-makers reduce their flexibility under a stress situation, sealing off new information and controlling deviant responses." (Janis, 1972). This concept draws the situation in which individuals behave rigidly during emergency situation because of high pressure in decision-making. A threat may result in (1) restriction of information processing and (2) constriction in control, such that power and influence can become more concentrated or placed in higher levels of a hierarchy. D'Aunno and Sutton (1992) posited that over-reliance to procedures, less participation, and workforce reductions cause rigidity in response. Thus, response rigidity may affect the success in both knowledge flow and control processes in the use of KMS to support EM (Plotnick and Turoff, 2011). These changes may lead to less varied or flexible system behavior for EM (Plotnick and Turoff, 2011; Staw et al., 1981).

The literature indicated the following characteristics or features that reduce rigidity in response: automatic notifications and free exchange of information (Plotnick and Turoff, 2011), less reliance to existing procedures, active participation, less anticipation of failure to handle external threat (Harrington et al., 2002), less anticipation of failure to handle internal threat, cognitive absorption (Agarwal and Karahanna, 2000), and mindfulness (Agarwal and Karahanna, 2000). Mindfulness refers to attention to detail with experience in similar situations that could reduce rigidity in response.

2.4. Dynamic response

This study aims to contribute to the critical success factors of KMS to support EM efforts. One is to clarify the unique characteristics of a disaster situation KM system design for EM. The other is to enable emergency managers to understand the key areas of best performance of KMS as well as to direct their operational activities to achieve their goal.

The success factors of Jennex and Olfman (2006) are retained and added with the situational quality to realize the success of a KMS to support EM. Each factor is discussed in detail and enumerated in Table 1.

3. Method

3.1. Theoretical framework

Fig. 2 shows the theoretical framework for this study. The KMS Success Model of Jennex and Olfman (2006) is relevant to the present study because its direct focus on KMS design success is to yield maximum benefits to individual and organization. This model can assist KM system design to support EM efforts. The model shows six constructs with variables to measure each construct. They are the following: (1) System quality measured by technical resources, KMS form, and level of KMS; (2) Knowledge quality measured by KM strategy/process, richness, and linkages; (3) Service quality measured by management support, IS KM service quality and user KM service quality; (4) Intent to use/perceived benefit; (5) User satisfaction; and (6) Situational quality measured by complexity of environment, cognitive absorption, rigidity of response, situational awareness, discipline and agility, roles, and dynamic response. These six constructs were posited to influence the design consideration of KMS for EM toward achieving the Net Benefit of the system.

The KMS success model guided the design decisions of EMIS. Hence, the constructs of the KMS success model of Jennex and Olfman (2006) and situational quality were mapped toward the possible design considerations for an EMIS. Table 2 outlines all five factors that influence the success of a KMS and shows how these success factors guide the design decision of the KMS-EM system. The design decisions for KMS success constructs are based on Jennex and Olfman (2006) and Murphy and Jennex (2006). The guiding designs for all the seven situational quality variables are based on Turoff et al. (2004) and Snowden (2002). Some of the guiding designs may overlap with system quality.

3.2. Client organization

The client for this research is the Disaster Division of the National Security Council of Malaysia (NSC). The NSC focuses on all national security issues such as racial harmony, boundary safety, wartime protection, defense, global diplomacy, emergency management, cyber safety, religion, maritime security, constitutional monarchy, and national health threat. The top position in NSC is the Secretary at the federal and state

Table 1
KMS critical success factors to guide KMS design decisions for EM.

Critical success factors (CSF)		Operational definition	Operational measures	Sources
CSF1	System quality (SQ)	SQ refers to the KMS capability to "perform the functions of knowledge creation, storage/retrieval, transfer, and application; how much of the knowledge is represented in the computerized portion of the OM; and the KM infrastructure." (Jennex and Olfman, 2006, pg. 40)	SQ1: Technological Resources SQ2: KM Forms SQ3: Level of KMS	Coombs et al., 2001; Gable et al., 2008; Stein & Zwass, 1995; Alavi and Leidner, 2001; Davenport et al., 1998; Ginsburg & Kambil, 1999; Sage & Rouse, 1999; Davis, 1989; Sedera & Gable, 2004; Jennex & Olfman, 2001; Wu & Wang, 2006
CSF2	Knowledge quality (KQ)	KQ refers to the extent to which the knowledge and KM processes are computerized and integrated to make the right knowledge available to support current activities, regular work practices, and decision-making based on different knowledge needs at different levels.	KQ1: KM Strategy/Process KQ2: Richness KQ3: Linkages	Orth et al., 2011; Jennex and Olfman, 2006; Hansen et al., 1999; Koskinen, 2001; Brown et al., 2006; Jennex and Olfman, 2006; Cross & Baird, 2000; Davenport et al., 1998; Sage & Rouse, 1999; Wu & Wang, 2006
CSF3	Service quality (SerQ)	SerQ refers to adequate service support from management, user organizations, and IS organization to enable accuracy, sufficiency, timeliness, relevance, usability, and comprehension of the stored knowledge.	SerQ1: Management Support SerQ2: IS KM Service Quality SerQ3: User KM Service Quality	Jennex & Olfman, 2002; Alavi & Liedner, 1999; Cross & Baird, 2000; Davenport et al., 1998; Ginsburg & Kambil, 1999; Holsapple & Joshi, 2004; Malhotra and Galleta, 2003; Sage & Rouse, 1999
CSF4	Situational quality (SitQ)	SitQ refers to a set of unique characteristics of situation that demand different types of response, values, and attitudes with which the individual or group must deal with in a knowledge process of activity.	SitQ1: Complexity of Environment SitQ2: Situational Awareness SitQ3: Cognitive Absorption SitQ4: Discipline and Agility SitQ5: Roles SitQ6: Dynamic Response SitQ7: Response Rigidity	Seppänen et al., 2013; Hersey & Blanchard, 1969; Reddin, 1967; Snowden, 2002; French and Niculae, 2004; Turoff et al., 2004, Dorasamy et al., 2013; Boehm and Turner, 2004; Harrald, 2006; Jennex, 2004; Bellardo et al., 1984, Paton and Flin, 1999; Plotnick and Turoff, 2011; Turoff, 2002; Turoff et al., 2004, 2008; Mayer, 2002; Bui & Sebastian, 2011; Ashish et al., 2008; Madey et al., 2007, Harrald, 2006; D'Aunno & Sutton, 1992; Plotnick and Turoff, 2011; Gladstein and Reilly, 1985; Wu & Wang, 2006
CSF5	Intent to use/perceived benefit	IU refers to perceptions of KMS users toward the benefits that will sustain the users' intention to use KMS.	IU: Intent to use	Jennex & Olfman, 2002; Thompson et al., 1991; Triandis, 1980; Malhotra and Galleta, 2003; Yu et al., 2004; Alavi and Leidner, 2001; Doll & Torkzadeh, 1998; Venkatesh et al., 2003; Sedera et al., 2004
CSF6	User satisfaction	US refers to the desire to use KMS depending on their satisfaction with KMS.	US1: Content US2: Accuracy US3: Format US4: Ease of Use US5: Timeliness	Jennex, 2005; DeLone and McLean, 2003; Coombs et al., 2001; Wu & Wang, 2012

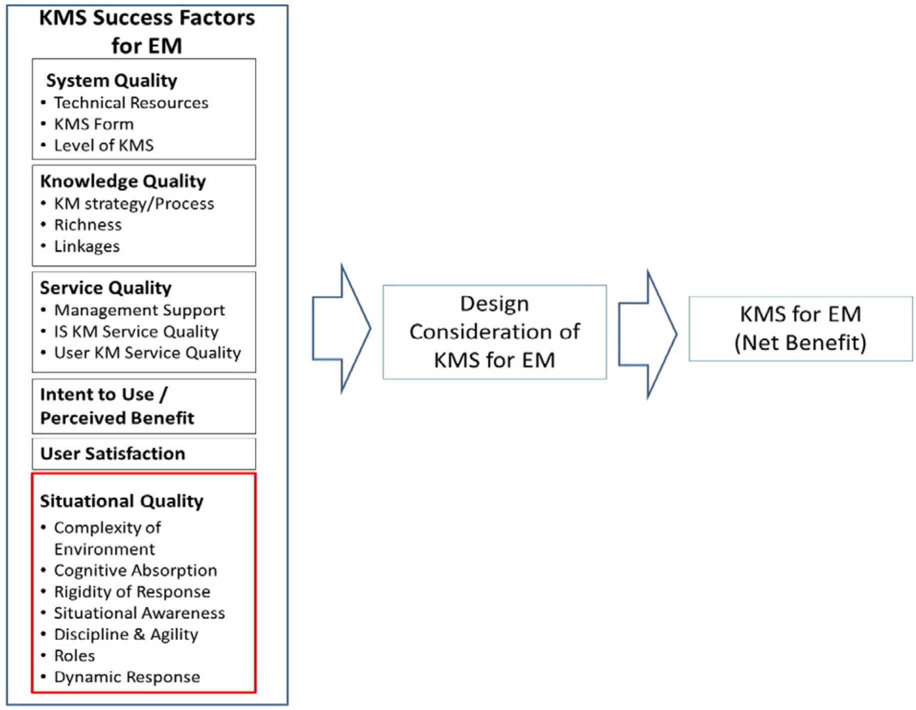


Fig. 2. Theoretical framework.

levels. An Assistant Secretary heads each unit or divisions. The participants for this study were the emergency managers of NSC at the federal and state levels. A total of 128 emergency managers, who are heading the state-levels disaster units in NSC and affiliates in 13 state and federal-levels were involved in the various data collection stages and evaluation.

3.3. Action research

The idea of implementing a KMS as the proposed solution intends to make life-saving knowledge available as explicit knowledge within an integrated single-view platform (Orth et al., 2011). To accomplish this objective, action research (AR) was chosen as the suitable approach for this study with action and research as intended outcomes. AR provides the flexibility and responsiveness needed for effective changes; and checks the adequacy of data and conclusions for this study. AR has the ability to solve real-life problems collaboratively and to be used for thesis fieldwork. We have gathered selected AR studies in IS domain limited to EM to understand how similar studies were initiated and implemented. Studies that have used AR involving IS and EM are very limited. Four IS for EM papers with AR as their research approach were identified (Dorasamy et al., 2011; Dorasamy et al., 2013).

In AR, theory should guide action, and a theoretical framework must be presented. Otherwise, the intervention action will lose its validity in research (Avison et al., 2001; Brydon-Miller et al., 2003; Davison et al., 2012). Experiences gained from action will then contribute to the further development of theory (Avison et al., 2001). Canonical Action Research (CAR)[3] was applied in this study. Based on the action research and the theory applied, the complete research design and processes are illustrated in Fig. 3.

Fig. 3 is composed of two sections: (1) Action Research and (2) Theory. These are shown on the far left side of the figure. The first section shows three key components in Action Research: (1) Problem; (2) Introduce and Implement Change; and (3) Problem Solved. Each of these components is mapped with the five stages of Canonical Action Research. Stage 1: Problem Diagnosis, identifies the problems at hand. Stage 2: Action Planning; and Stage 3: Invention, introduces a suitable change agent, which in this study is a KMS. In Stage 4, Evaluation and Stage 5: Reflection, the system was then evaluated by the NSC to ascertain the effectiveness of KMS in solving the problem at hand. In the second section of Fig. 3, Theory, the underlying theoretical foundation to guide design consideration for this study is illustrated and mapped toward guiding the system design considerations of the proposed KMS for disaster. The KMS Success Model by Jennex and Olfman (2006) is the kernel theory for this study, and added with a new dimension called situational dimension.

Canonical Action Research (CAR) was employed because EM is a complex social process that is best examined by this approach (Dorasamy et al., 2011). Action Research is a systematic approach in which a researcher is directly involved in solving a real world problem for an organization by using some form of guided theory. This is done specifically by introducing changes into social processes and observing the effects of these changes. CAR enables researchers and practitioners to achieve better solutions and research findings from an intervention without undermining the current practices and changes. CAR's five stages guided the study with the underlying theoretical foundation based on Jennex and Olfman's KMS success model (see Fig. 4). Rigorous cycles of activities were conducted for each stage of CAR to avoid any bias and misinterpretation of requirements to design iCEMAS for NSC and community.

Data were collected at two different stages: pre-system and post-system. Fig. 5 illustrates the detailed activities of data collection and evaluation. The following activities were carried out during pre-system and post-system:

i. Problem diagnosis

Preliminary interviews were conducted to understand the current challenges in NSC.

ii. Action planning

A presentation was carried out on the proposed system as a possible systemic solution for the challenges. The various constructs were

[3] CAR is a type of Action Research that will be described in Section 3 Method.

Table 2
Guiding KMS success factors for the EMIS design.

Constructs	Success variables	Guiding KM system design (Jennex and Olfman, 2006, Murphy and Jennex, 2006, Snowden, 2002 and Turoff et al., 2004)
System quality	Technical resources	– Existing software, hardware, network, database and platform
	km form	– Knowledge input forms – Knowledge representations (output) – Knowledge retrieval time expected
	Level of KMS	– Level of usability expected – KMS functions at different level – Federal, District and State
Knowledge quality	KM strategy/process	– How system can benefit productivity? If benefit, then motivated to use.
	Richness	– Usability features: GUI, Menu, object-based – What knowledge to store, transfer, disseminate
	Linkages	– Links required between various knowledge
Service quality	Management support	– Overall management support to encourage knowledge sharing culture
	IS KM service quality	– Existing system capabilities
	User KM service quality	– Service quality required by KM team: responsiveness, effectiveness, and competence level
User satisfaction	User satisfaction	– User interface design – Usability – Service and System design
Intent to use/perceive benefit	Intent to use/perceive benefit	– Features and functions that is perceived as beneficial for productivity. E.g.: event calendar, alerts, KM team chat functions – Extremely simple interface
Situational quality	Complexity of environment	– Learning on past, present and future of disaster – designate changes in priorities, filtering and delivery options
	Discipline & agility	– Access to all knowledge
	Roles	– Ability to change roles and responsibility
	Dynamic response	– Used regularly
	Cognitive absorption	– Extremely simple interface
	Situation awareness	– Flagging by subject matter – Expertise location system – A common shared database structure – access relevant knowledge or expertise
	Rigidity of response	– Access to all knowledge – freely exchange knowledge
Net benefits	Net benefits	– Productivity measures

operationalized in the context of a KMS implementation. Survey method was utilized in the form of seven-point Likert-type scales for all individual-level perceptual measures. The measurement items are presented in the first table of Appendix A. Once the user requirements were collected through interviews and survey, the system requirement was finalized with solution features for the challenges faced in NSC. The proposed system was presented to NSC for final approval.

iii. Intervention

System was built and tested.

iv. Evaluation

The prototype system was presented to NSC officials in the form of a simulation test. Structured questions, open-ended questions and interviews were carried out to capture the evaluation of system. A set of open-ended questions for the evaluation stage was used to obtain responses from emergency managers. The second table of Appendix A lists the questions.

This evaluation should be carried out as a follow-up for any evaluation exercises done with similar morphology with this study. It provides an effective method for EM professionals and researchers to carry out the evaluation procedure of determining the data needed. The measurement of KMS success table can be used before implementing a system for EM to gain widespread broad situational information from all emergency stakeholders. Data from this survey will help understand the possibility of implementing a KMS. The survey will also be useful during the post-system period to indicate whether influence of a specific variable exists. This can be done by coding the data obtained from the survey in a dichotomous form. A score of 1 will imply a positive response, and a score of 0 will imply a negative response of an EMIS.

Once the system is designed and ready for evaluation by users, the 12 post-system evaluation questions should follow up. This data can be analyzed by coding the responses in a table with columns on positive, negative, positive with recommendation, or no comments/neutral responses. Summarizing all responses into this table will give light to the real value of the system to the domain.

The System Usability (SUS) was used to assess the usability of the system. SUS is an inexpensive tool for assessing the usability of an information technological product, including web sites, application software, and hardware. SUS consists of ten statements, which are five positive and five negative statements. One overall question, with score ranging from 0 (negative) to 100 (positive), was included to analyze the effectiveness and user friendliness of the system. The system was considered acceptable if the resulting rate was above 70. This evaluation stage aims to find answers for the following questions (Baskerville, 1999):

- Were the theoretical effects of the action realized?
- Did these effects relieve the problems?
- If unsuccessful, should some framework for the next iteration of the action research cycle (including the adjustment of the hypotheses) be established?

The evaluation process ended with user acceptance certificate signed by the client. Canonical action research method ends with reflection. During this stage, the prototype was assessed for its success via a triangulation data method. These stages are shown in Fig. 5. Data collected through these stages were analyzed using SPSS (for basic frequency test), and NViVO 9 analysis tool (for word frequency test) as well as various other qualitative methods to evaluate whether the system could solve the problem in hand.

This study used purposive sampling because people were consciously selected on a particular set of attributes (McNiff et al., 2003). All NSC officials in Malaysia had the opportunity to participate in the data collection and system implementation. The population size of this group is 128 people. The population breakdown and the data collection methods are reported in Table 3. The sampling was conducted on the NSC and relevant supporting agencies. The AR attempts to conduct research and action within a social setting, and thus, generalization to the larger population is not the main aim of the research. A more rational detailed discussion of AR follows in the next section.

3.4. Change agent: iCEMAS

Theoretically, the KMS success factors for developing a system to support EM was supported by the quantitative results. However, for an in-depth study, various methods can be implemented to ensure the real impact of any study. Hence, an open-ended question was posted to all NSC officers in Malaysia to identify crucial factors in developing a KMS that can effectively support the NSC's EM-related operations. Given the challenges and feedback collected, a system was developed that will support both community preparedness and emergency management engine of Malaysia, namely Integrated Community Emergency

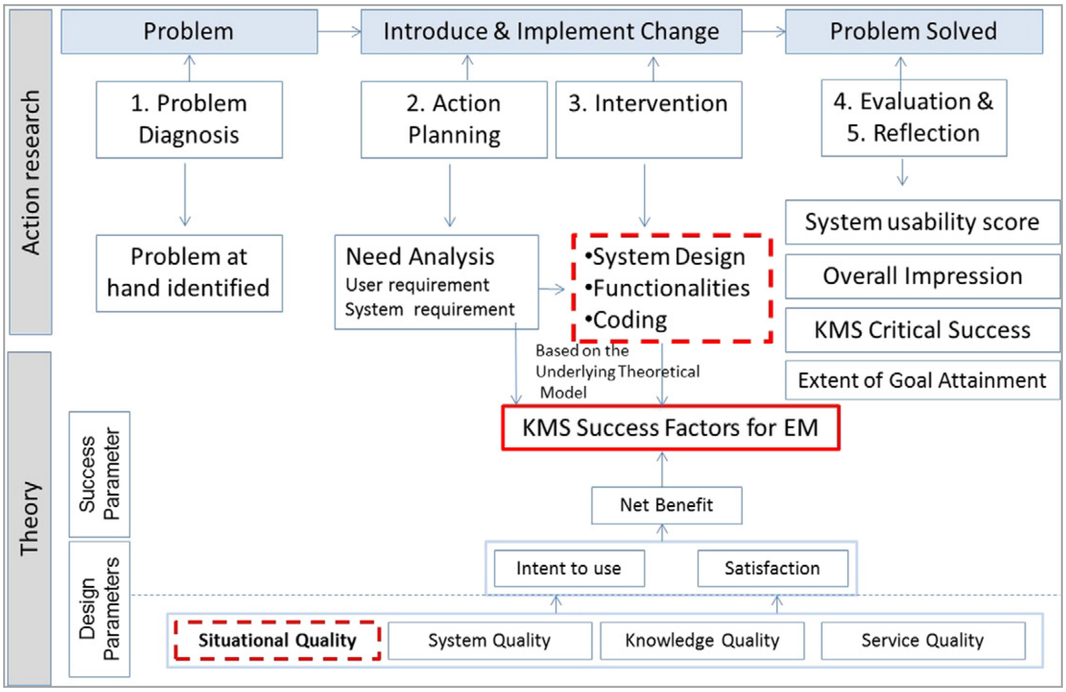


Fig. 3. Overall research design and process.

Management and Awareness System (iCEMAS). It is a web-based system that is conceptualized, designed, and implemented to aid emergency management efforts in Malaysia, in the context of natural disasters. Natural Disasters such as floods, tsunamis and landslides, are unavoidable. However, implementation of systems (driven by IS) can reduce the impact and ramification of disasters, particularly if the system can assist both communities (citizens) and local authorities in preparing for disasters. We suggest that a KMS can enhance emergency management and resiliency in Malaysia. The system is a "proof of concept". This prototype has been tested in NSC Malaysia.

In essence, iCEMAS has two main components. The first is MySedia, which is a community portal that aims to reflect "Malaysia Sedia" for disasters, and serves the need of every Malaysian who has deep concern on issues that pertain to disasters and the classifications (and impact) of natural disasters. This portal is dedicated to all Malaysians to increase resiliency and readiness toward disasters. It is a platform for knowledge sharing, community notification, learning points, and online discussions

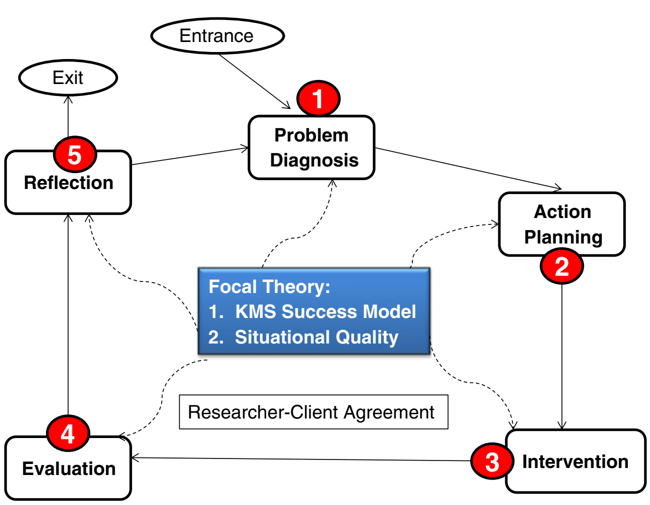


Fig. 4. Five stages of canonical action research.

using tools such as crowd sourcing, forum, and social media. The second is CEMAS which is a system that serves the requirement of any emergency management agency such as the NSC as central repository for managing assets and expertise in planning for and responding to disasters. The system also improves internal communication, coordination and collaboration between the three levels of NSC – federal, state, and district. A multi-layered architecture of KMS using object-oriented approach was applied to allow the integration between various components of CEMAS. This method makes the system applicable at any level of a company.

3.4.1. System design considerations

Further to the generic guiding design considerations based on each of the KMS success factors as presented in the Table 2, we analyzed the specific design features that is relevant to address the three challenges faced by NSC. Then, we combined the system design considerations as suggested by previous research based on applied KMS for disaster with user requirements provided by NSC officers. The following sub-sections describe the system design considerations that have been collected from past research and presented for each of the three IS challenges faced by NSC to support EM in Malaysia.

3.4.1.1. Challenge 1: problems in 3Cs (communication, coordination and collaboration). Turoff et al. (2004) emphasized that an EMIS should include priority setting, filter option, and delivery option during emergency response situations. Except delivery option, iCEMAS has included all the above 3Cs attributes. The availability of people during disaster, free exchange of information, access to relevant data or expertise, and coordination by feedback are made available as suggested by Hale (1997), Turoff et al. (2004) and Dynes and Quarantelli (1977). These factors enable the system to observe dynamically the changes and required responses for EM (Turoff et al., 2004). Moreover, source, actions, interest, and concerns are crucial for any communication tools. All communication can be traced based on registered members, actions, activities, interests, and concerns via group discussion or forum. Roles are another key attribute for any emergency information system (Turoff et al., 2004). Roles are included for each members of the system. The role can be changed by admins based on the privilege of users. Turoff

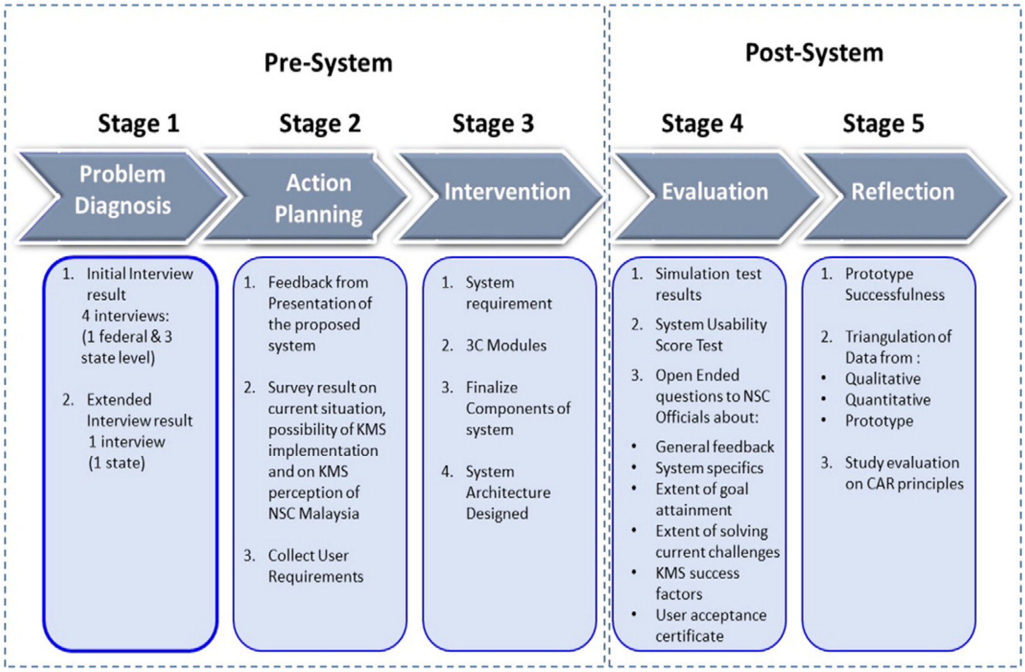


Fig. 5. Activities for data collection and evaluation.

et al. (2004) outlined 12 fundamental roles that should be provided in any emergency information systems. French and Niculae (2004) emphasize the importance of having diary, financial, and workflow management. These management systems are beyond the scope of this research. However, these features are crucial for collaboration activities. Socialization (Nonaka and Takeuchi, 1995) includes the 3C components, such as forum and member discussions. Members, such as NGOs, community, victims, volunteers, NSC officers, police, and rescue officers, are able to communicate and share knowledge. This process of socialization enabled the elicitation of tacit knowledge that otherwise may not have been revealed. This information is shown in Table 4.

3.4.1.2. Challenge 2: data management. Expertise bank, assets records, lessons learned, and disaster records were clearly lacking in NSC. These components are essential for any EMIS that is knowledge based. Turoff et al. (2004, p.8) emphasized that "A crisis response system is an information system that has to be an integrated communication and data system where the people involved, their talents, concerns, immediate problems, actions taken, actions planned, situation information, and consequences information is all part of the underlying database and structure." The expert list is an important element for iCEMAS. Emergency managers can search people record by keywords such as "expert" or if they are looking for flood experts, two words, "expert" and "flood" will bring details about flood experts. Hence, communication with experts can be established, and better solutions for problems can be obtained at hand.

The commonly shared database (Turoff et al., 2004) is extremely vital because some actions are done based on incomplete information. By having a commonly shared database, efforts toward channeling all information to the shared database can be made. Keyword search report is relevant to ensure that the database further equipped with required keywords. A system should be able to track keywords regardless of whether they were found. For example, keyword search for "experts" and for "flood disaster" should result in a tracking expert list on people in the records. Keywords that are not found should be reported and made available for future use. However, this function was not possible for iCEMAS because of the scope of the research. The flexible search tool and the GUI are recommended by French (2013). Flexible data and information management system are needed for the ease of use of a database. Knowledge stored should be accessible with easy search tool with natural language and GUI. This attribute was considered for the design of the user interface. Search functions are available for both the entire systems and individual tables in database.

We included six tables in the database component: records on disasters, assets, drills, lessons learned, people, reports, and SOPs. The first four tables present historical and current data stored in 2D table format for easy search and reference. Data on past disasters, asset availability, drill information, and disaster lessons were not present in a manner that is easy to access. The database was set to private, and only NSC staff could view or edit the database. Public users were not allowed to open these private files. Each table contains a set of fields that are relevant and created based on literature. Table 5 list all these attributes.

3.4.1.3. Challenge 3: information, knowledge sharing, and dissemination. Information, knowledge sharing, and dissemination challenges refer to the ineffectiveness of accessing the right information, knowledge sharing, and dissemination using an effective system. Based on the literature, we added the key attributes of information and knowledge in iCEMAS. These are keyword search, individual file search, search by responsibilities, free access to information, delegation of authority, conduct oversight, collaborative working tools, and discussion tools. Keyword search is relevant for information and knowledge seekers. The system provides this function for overall system search as well as for the individual file search within the database. Finding information and knowledge in a short time is vital for EMIS (Turoff et al., 2004). Responsibilities of members are recommended by Turoff et al. (2004) and Hale (1997). Searching by responsibility helps emergency managers to seek relevant actions or even change responsibilities depending on the situation. This attribute is added in iCEMAS. Free access to information, delegation of authority, and conduct oversight to avoid information overload issues are attributes recommended by Turoff et al. (2004). Information overload is common for extreme events such as disaster situations. Hence, the effect of information overload must not hinder the decision-making process. Tacit knowledge must be recorded. Tacit knowledge is usually recorded via observations, experience sharing, and practice (Kim, 1998). According to Kim (1998), tacit knowledge is a "dynamic inventory function" to back up short supply of resources and lifesaving knowledge during disaster. To facilitate tacit knowledge,

Table 3
Data collection method by CAR stages.

CAR stages	Data collection method, objective and instruments	Unit of analysis
Stage 1: problem diagnosis	• 2 preliminary interviews • Objective: To identify challenges, causes and possible IS solution • Instruments: 4 general questions on NSC and 4 general questions on KMS for NSC	Top management only (Secretary, Assistant Secretary) • Federal level: NSC, Disaster Division, Prime Minister's Dept. • State level: NSC Selangor, Disaster Division
Stage 2: action planning 1. KMS perception 2. User requirement	• Quantitative: survey form – Objective: To understand the perception of NSC community in Malaysia on KMS support for EM so that a true value of critical success factors can be derived from this research in order to contribute to the theory – 5 Likert-scale survey questions with 140 items • Qualitative: interview – Objective: To understand what are the important features/issues/-components/characteristics that must be taken into account in designing and developing a KMS to support EM for NSC based on their experience. – 1 item on user requirement for the proposed system	128 NSC officers who are top management team in the 15 NSC state offices nationwide in Peninsular and East Malaysia.
Stage 3: intervention 1. System demo 2. Testing 3. Review & revise	• User requirements were mapped toward the system design and KMS success factors to guide the design. • System activities added based on input, processing, output, feedback and control • Testing includes: Pre-test, Controlled experiments, and Cooperative evaluation.	Not applicable
Stage 4: evaluation	• Final showcase with the system demo for feedback and to obtain understanding of process • Simulation test followed by quantitative and qualitative data collections – Objective: To evaluate how effectively the prototype system was supporting the emergency management in NSC – Setting: Indoor computer-aided simulation – Disaster scenario for test: Flood – Qualitative: Interview with each officers – Data collected: Time recorded for processes with and without KMS • Focus group meeting with 24 NSC officers and other government agencies related to emergency management. System was demonstrated for their overall impressions and feedback. – Quantitative: using system usability score (SUS) – Qualitative: open-ended survey form	10 NSC officers who are decision makers in emergency management 24 NSC officers and other supporting government agencies in a focus group meeting set up
Stage 5: reflection	• 7 AR validation criteria • Prototype success fit test • Mapping prototype with qualitative and quantitative results to make AR claims.	Not applicable

collaborative working tools are required (French, 2013). As for iCEMAS, collaborative tools must be enhanced. Garvey and Williamson (2002) asserted that tacit knowledge is best conducted by multi-disciplinary discussion. Discussion tools are provided in iCEMAS. Explicit knowledge is equally important as tacit knowledge for any KMS. Flexible system formats are important for access of explicit knowledge. Ideally, the knowledge is presented by using natural language (French, 2013).

Table 4
3Cs attributes for iCEMAS.

3Cs attributes	What will be applied for iCEMAS?	Sources
1. Priorities setting 2. Filter option 3. Delivery option 4. Availability status 5. Freely exchange information	All are added except for delivery option.	Turoff et al., 2004
6. Access to relevant data or expertise	Added	Hale, 1997
7. Coordination by feedback	Added	Turoff et al., 2004; Dynes and Quarantelli, 1977
8. Source 9. Actions 10. Interests 11. Concerns	All Added	Turoff et al., 2004
12. Roles	Added	Turoff et al., 2001; Turoff et al., 2004
13. Diary management 14. Financial management 15. Projects workflow	Only Diary was added. All others were not included (beyond scope)	French and Niculae, 2004
16. Process of socialization	Facilitated via Forum, Twitter, Group discussions	Yoong & Gallupe, 2001; Nonaka and Takeuchi, 1995; French, 2013

Table 5
Data management attributes for ICEMAS.

Disaster data management attributes	Will it be applied for ICEMAS?	Sources
Disaster events: – People involved – People talents – People concerns – Immediate problems – Actions taken – Actions planned – Situation information – Consequences information	Added as Disaster records of past events.	Turoff et al., 2004
Experts list – Roles – Responsibilities – Interests – Concerns	Added as People records. One of the category type is Expert. Roles were assigned by NSC.	Hale, 1997; Turoff et al., 2004
Common shared database	Applied. Database is common to all NSC officers and shared.	Turoff et al., 2004
Query tool – natural language, GUI	Added. Simple search function for the whole system and search within database were provided. GUI is applied for ease of use.	French, 2013

Table 6
Information and knowledge attributes for iCEMAS.

Information and knowledge	Will it be applied for iCEMAS?	Sources
1. Keyword search	Added	Turoff et al., 2004
2. Search by responsibility	Added	Hale, 1997; Turoff et al., 2004
3. Free Access to relevant data or expertise	Added	Turoff et al., 2004; French, 2013
4. Record tacit knowledge	Added	Garvey & Williamson, 2002; French, 2013
5. Explicit knowledge	Added	French and Niculae, 2004
6. Lessons learned	Added	Jennex, 2007
7. Event log, chronology roles, notifications, content visibility, hypertext linkages	Added	Turoff et al., 2004

However, excessive explicit knowledge might be avoided for simplicity, whereas visibility of knowledge is critical. Lessons learned for every activity, programs, disasters, and other events are to be recorded. Lessons learned provide the best understanding of a situation and the best way to manage it in the future. In the disaster domain, very frequently, the lessons learned are left as tacit knowledge, and are never recorded in the database for easy search and use (Jennex, 2007). Event logs, chronology of events, roles, notification, content visibility, and hypertext visibility are attributes suggested by Turoff et al. (2004) for EMIS. All the attributes are added in iCEMAS as indicated in Table 6.

3.4.2. End users and system focus

The intended features are grouped based on the three IS challenges in NSC:

i. Community/public - A dashboard that contains:

3Cs related features	Data management features	Information/knowledge related features
• To know their community and the strength for better rescue/response • To seek professional advice from disaster community via communication and collaboration platforms • To provide alerts on disasters occurred in surrounding area via registered email groups. • To capitalize on the advantages of social networking such as twitters to improve disaster communication • To access available disaster programs and activates hosted by NSC such as the frequent disaster awareness programmes, drills and simulations	• To register as member for group discussion and forum participation	• To be aware of disaster risks and able to create their own emergency plan thereon; • To know their readiness and resiliency levels from time to time • To understand lesson learned from past disasters for preparedness and improved resiliency • To know various information on relief, NGO, shelter, disaster resources, trainings, vulnerable areas, and mitigation efforts of the government

ii. To NSC and related agencies (Fig. 6 shows some of the components of iCEMAS):

3Cs related features	Data management features	Information/knowledge related features
• To make current and future disaster related programs known to the vulnerable community • To communicate with first responders at ground level, such as people close to victims • To communicate with affiliates in relation to community readiness level • To reach the members of community to form first responder strength at ground level • To provide a platform for better coordination among first responders from community, community heads and leaders, and with NSC affiliates, such as district officers	• To have easy access to past disaster records on what actions were taken, what had happened, lessons learned for the incident, and for future recommendation • To have easy access to records of types of drills conducted, where they were conducted, what were their results, how to improve, and what type of disaster • To have easy access to current asset records on availability, current condition, the person in charge, and the location of the assets kept • To have easy access to reports such as internal, periodical, and international reports • To have easy access to the SOP, especially for novice officers, by level (federal, state and district), and by disaster types • To have easy access to lessons learned for each disasters occurred in Malaysia to enable easier decision-making	• To assess and understand the community readiness level • To inform the community on relevant issues that are critical for community preparedness • To educate vulnerable community on emergency plans and disaster supplies during certain disasters

4. Results

Our aim was to find answers for the following questions as suggested by Baskerville (1999):

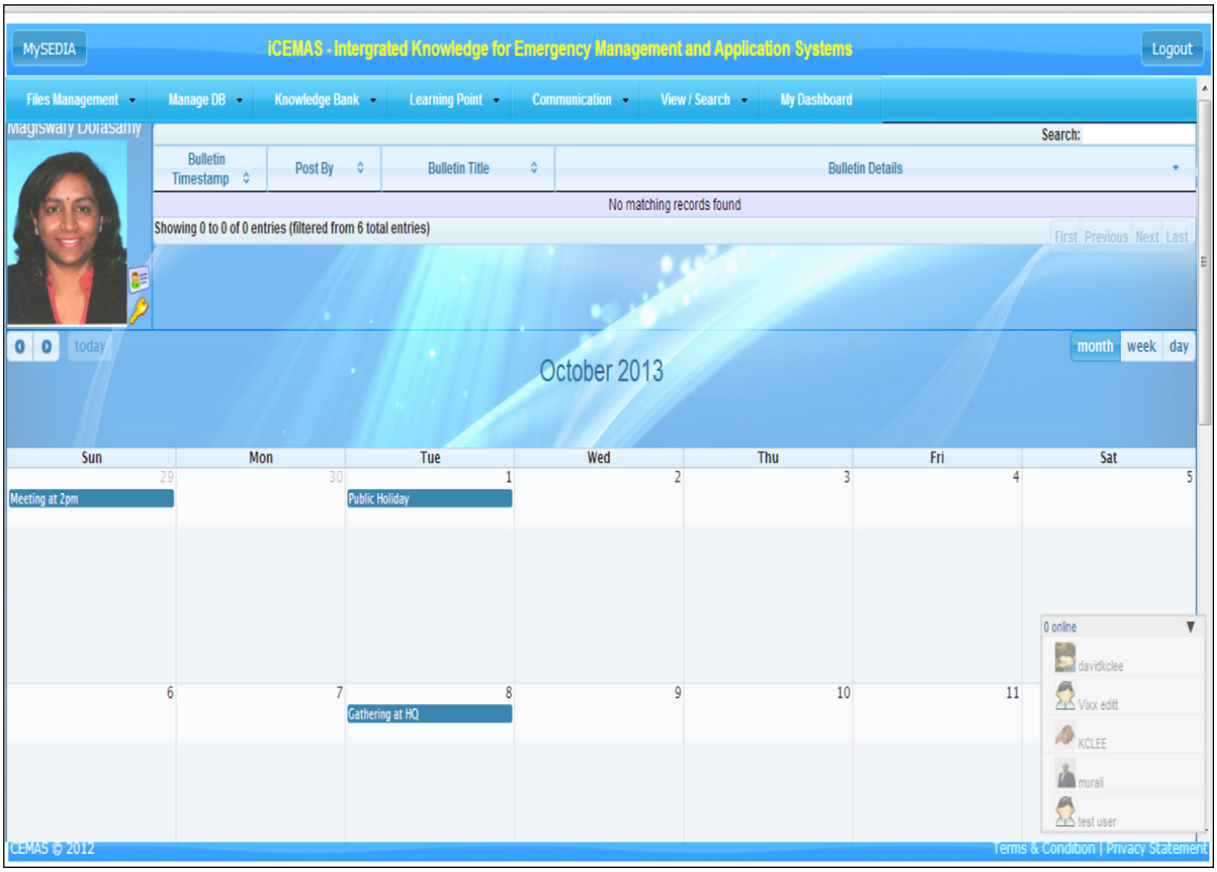
i. Were the theoretical effects of the action realized?
ii. Did these effects relieve the problems?

The findings from the evaluations conducted are described as below:

4.1. Perception on KMS for EM by emergency managers

This simple survey aimed to understand the perception of emergency managers on KMS for EM. A total of 72 officers responded. A plurality (30%) of the responses were collected from NSC Putrajaya (the headquarters of NSC), followed by the Selangor state officers, which accounted for 14% of the total responses. Slightly more than half (57%) of the total respondents were between 18 and 34 years old. A total of 36% were in the 35- to 54-year-old category. The remaining 7% are in the 55 and older category. The majority (75%) of the NSC respondents were male. A probable reason is that the NSC is very much action based and requires field work. Hence, it is a more male-dominated organization. Of total respondents, 83% were management officers classified as Group A. The groups are standard categories given for government officers. Particularly, Group A consists of officers with high qualifications and have spent many years with the organization. Secretary for State Security is the NSC's top position in every state, followed by the Assistant Secretary. The officers who are tasked to lead a certain division within the state NSC (e.g., Disaster Division) are classified as Group A officers. Administration officers are classified as Group B (e.g. Asst. Officer,

Fig. 6. iCEMAS dashboard and disaster knowledge bank for emergency managers.


MySEDIA
iCEMAS - Intergrated Knowledge for Emergency Management and Application Systems
Logout
Files Management
Manage DB
Knowledge Bank
Learning Point
Communication
View / Search
My Dashboard
Search:
Bulletin Timestamp
Post By
Bulletin Title
Bulletin Details
No matching records found
Showing 0 to 0 of 0 entries (filtered from 6 total entries)
First Previous Next Last
today
month week day
October 2013
Sun Mon Tue Wed Thu Fri Sat
Meeting at 2pm
Public Holiday
Gathering at HQ
0 online
davidkclee
Vixx edit
KCLEE
murali
test user
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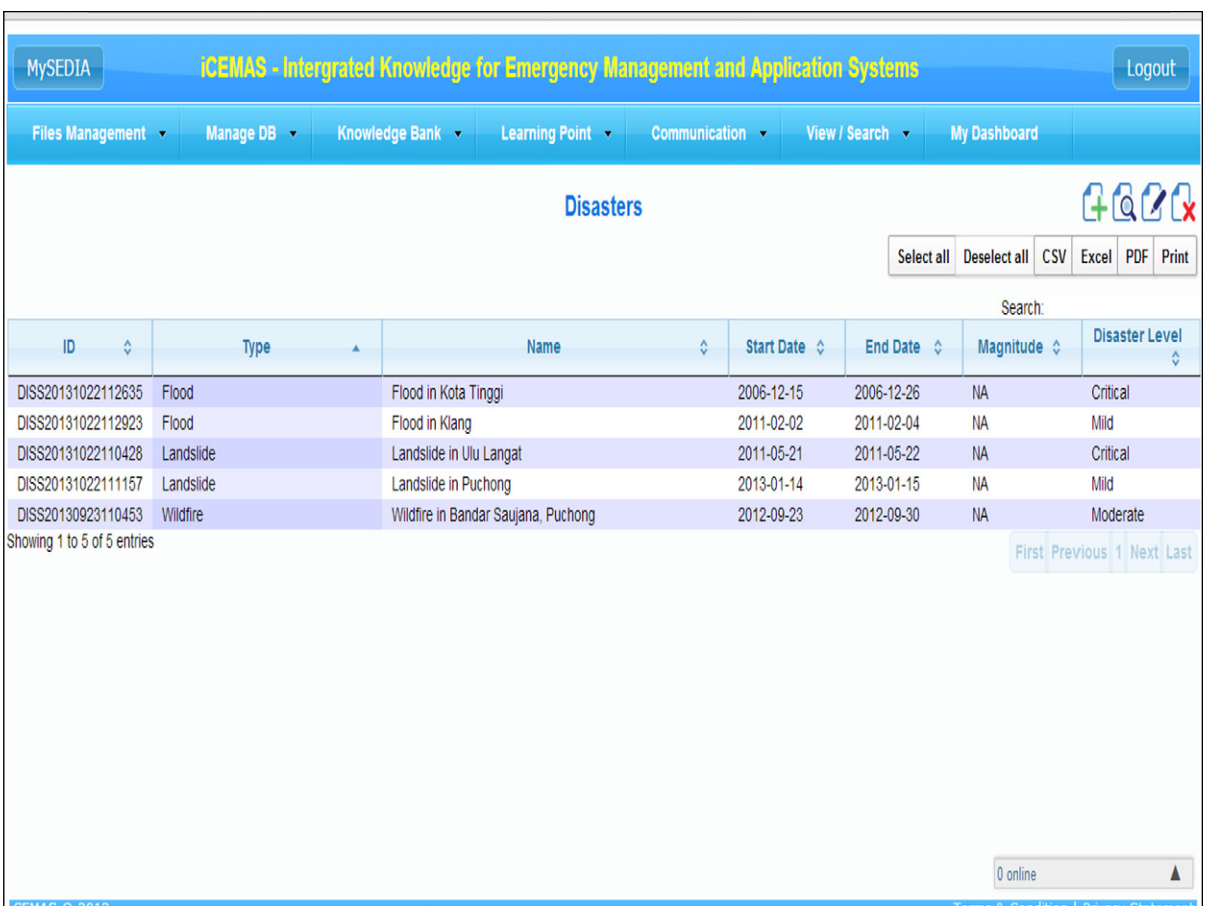
MySEDIA
iCEMAS - Intergrated Knowledge for Emergency Management and Application Systems
Logout
Files Management
Manage DB
Knowledge Bank
Learning Point
Communication
View / Search
My Dashboard
Disasters
Select all Deselect all CSV Excel PDF Print
Search:
ID Type Name Start Date End Date Magnitude Disaster Level
DISS20131022112635 Flood Flood in Kota Tinggi 2006-12-15 2006-12-26 NA Critical
DISS20131022112923 Flood Flood in Klang 2011-02-02 2011-02-04 NA Mild
DISS20131022110428 Landslide Landslide in Ulu Langat 2011-05-21 2011-05-22 NA Critical
DISS20131022111157 Landslide Landslide in Puchong 2013-01-14 2013-01-15 NA Mild
DISS20130923110453 Wildfire Wildfire in Bandar Saujana, Puchong 2012-09-23 2012-09-30 NA Moderate
Showing 1 to 5 of 5 entries
First Previous 1 Next Last
0 online
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personal secretary). In the district level, the top position is the District Officer followed by Pegawai Tadbir Daerah officers (i.e., PTD or the Officer of District Administration) who are district-level administration officers. They are placed by NSC in each district to assist in implementing the agenda. The survey also included support officers classified as Group C, such as clerk and technician. In most cases, they are the ones who will manage the database, information flow, and meetings.

4.2. Simulated environment test result

A disaster scenario was created to test the proposed system. The scenario given was on flood disaster. The emergency managers were briefed that flood is forecast to occur in a heavily populated city called Klang because the river water level is expected to rise in 5 h. The following result was obtained at NSC. The result indicated that emergency management could benefit in terms of critical time saving during decision making. Table 7 summarized the time recorded before the system and with the system. Time saving is also recorded.

The time taken to accomplish each of the five tasks without KMS implementation was obtained from the NSC officer's statement, whereas the time taken with iCEMAS was obtained by the researcher using a stopwatch tool for each of the tasks. The current processes without iCEMAS are described below.

1. **How many boats can we deploy to the location for rescue operation? Who is in charge?**

The current situation revealed that the officer had to call the Fire and Rescue department officers and ask if a boat was available for the location. The Fire and Rescue department had to make a few calls among their branches to determine the number of boats. This process usually takes **10 min**, according to an NSC officer.

2. **Have we conducted any drills in Klang before? What was the outcome?**

This question required the NSC officer to identify if any drill was conducted for this location. Under the present situation, the officer had to ask the district-level of the Security Council of Klang. The officer incharge for Klang had to check his/her voluminous of files for information, which usually takes **1 h** to accomplish.

3. **Who can we consult about the possibility of the increase in water level?**

This question required the NSC officer to identify the flood expert, which requires database access. Under the present situation, the officer had to make several calls to various departments or agencies. For example, if the officer requires information on river, rain, and flood information, he needs to call the Department of Irrigation and Drainage (DID), being the expert in water-related resources. The information is usually explicit and usually takes **10 min** to be obtained.

4. **Did a disaster previously occur in this location? What action was taken? (Disaster record)**

Under the present system, the officer has to make several calls to local heads of villages or the NSC district officer for Klang district. NSC has the list of all local heads of villages in each district. However, this list does not include the town parks because they fall under the local authority, such as Klang Municipality Council. These are the sources of information on past disasters. According to the NSC officer, contacting these people will usually take **15 min**.

5. **Any lessons learned from flood? (Lessons learned)**

At present, the lessons learned were not recorded on any system or even in traditional paper files. This information remains in tacit format that can only be obtained by a series of socialization. For example, when discussing about this topic, the officer revealed about the experience in conducting drills and preparedness activities in locations with apartment residents. According to the officer, encouraging preparedness among people living in apartment complexes is difficult. Even anti-dengue spraying is difficult to be implemented in apartments because the consent and approval of the residents are required. In this context, the lessons learned from this situation are that the community generally takes things for granted and that ignorance is the real reason behind this. Given that no records are available on previous experiences, the only way to obtain the information is through socialization sessions, such as round table discussions and community-based preparedness strategy (CBPS). Hence, recording the time needed to complete this process is impossible.

This result is a very good stimulus for generating serious interest on the part of the EM professionals. In addition, it could be an excellent methodology for generating improvements to any existing operation for the benefit of the EM professionals. Our contemporary review of literature on EM suggests that most often systems to support EM are often developed without taking socio-technical factors into consideration. Furthermore, the situational context of implementing EM systems remains under examined. Our findings support pioneering work by Turoff et al. (2004) that design of any EM system should be backed by solid theory. Our system is guided by Turoff's et al. (2004) 12-point design considerations for any EM system. Vital considerations from key stakeholders must be taken into consideration prior to implementing any EM system. In the context of this study, we combined use of both in depth discussion with emergency response managers and blend these ideas with that of sound theory on EM (Turoff et al., 2004). Only then the system was designed and tested in a real world environment, with feedback given by people who are actually involved in EM activities.

4.3. System usability score

Specifically, the system usability score was conducted post-implementation of iCEMAS. iCEMAS was rated either “Best Imaginable”

Table 7
Simulated environment result.
Source: Dorasamy et al., 2014.

Scenario based questions	Time taken		Time saved	Time saved in %
	Without iCEMAS	With iCEMAS		
1. How many boats can we deploy to the location for rescue operation? Who is in charge? (Asset)	Approx. 10 min	22 s	9 min 38 s	96.3%
2. Have we conducted any drills in Klang before? What was the outcome? (Drills)	Approx. 1 h	18 s	59 min 42 s	99.5%
3. Who can we consult about possibility of water rise? (People - Expert)	Approx. 10 min	16 s	9 min 44 s	97.3%
4. Any past disaster occurred in this location? What action was taken? (Disaster)	Approx. 15 min	32 s	14 min 28 s	96.4%
5. Any lessons learned from flood? (Lessons learned)	Based on tacit knowledge of officers	15 s	Infinite	100%

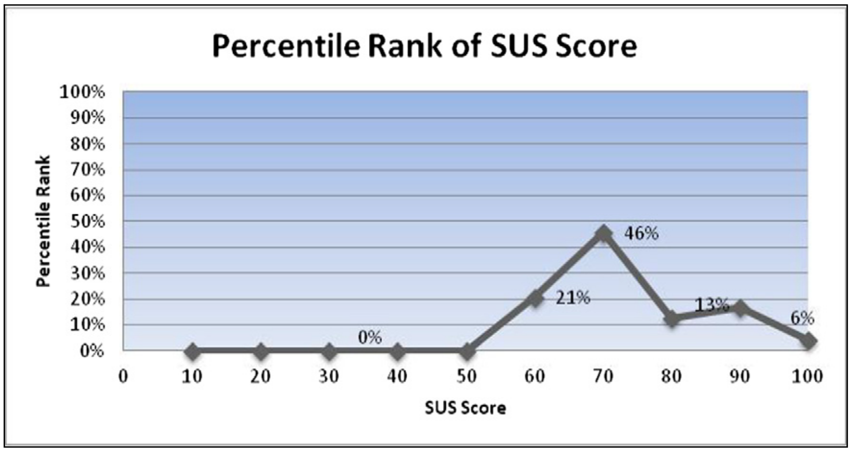

Fig. 7. Percentile rank of SUS score.

(4%), "Excellent" (58%), or "Good" (25%) by 87% of NSC officers who participated in the evaluation session. In addition, a system usability score (SUS) of **70.3** was obtained, thereby indicating that the system is highly effective in serving the intended purpose of the system. Overall, NSC officers concur that the proposed system can solve the current challenges faced for EM and will improve overall national disaster resilience. An SUS above 70 indicated that the system had high usability features and was favored by users for accomplishing tasks. Individual scores were plotted in a line graph shown in Fig. 7.

A total of 6% of officers gave a very high SUS rating in the range of 91 to 100 for the system (**92.5**). Roughly 13% rated between 81 and 90 and three officers (12.5%) rated between 71 and 80. A total of 11 (46%) officers rated the system with an SUS ranking between 61 and 70. The remaining 21% of the officers rated the system between 51 and 60. No SUS below 55 was recorded. The result is shown in Fig. 7. When the respondents were asked to select the overall user-friendliness of the system, one officer selected the "**Best Imaginable**" category which is the highest rank (rank 7th) in SUS. A total of 14 (58%) respondents indicated their experiences as "**Excellent**", which is ranked 6th. Six (25%) respondents selected "**Good**" and three (13%) officers selected "**OK**". This is shown in Fig. 8.

4.4. Feedback on overall impression of the system

At this stage, the iCEMAS was evaluated for extent of goal achievement. Twenty-four NSC officers were requested to evaluate and answer open-ended questions. The first goal of the client and researcher was to solve Problem 1, 3C challenges among the three different levels (district, state, and federal), which needs to be improved for better control and command. The user requirements for iCEMAS included a communication tool that was secured between all NSC staff regardless of level; seamless communication with others, such as government agencies, communities, and stakeholders; and group discussion with the possibility to create private discussions. The system was equipped with tools such as forum, member forums, member search, group discussions, social media (Twitter and Facebook), and e-mail functions. Approximately 91.3% of the respondents agreed that the system would improve the current 3C challenges faced.

The second goal of client and researcher was to solve Problem 2: Data regarding assets, drills, disasters, SOP,[4] reports, and lessons learned are not easily and systematically available. Users indicated that iCEMAS must have easy access to records, easy access to policies, rules and acts, and is easy to search for knowledge. The system was equipped with tool database approach with four tables (assets, disaster, drills, and lessons learned by disaster) and links to important documents and information such as SOP list, and report repository. The result was 100% of the respondents agreed that the system is able to improve the current challenges faced in terms of EM.

The third goal of client and researcher was to solve Problem 3: Information and knowledge on EM are not disseminated and shared in an integrated manner. An integrated platform was needed to facilitate knowledge sharing because assets, drills, disasters, SOP, reports, and lessons learned must be available during all three stages of the disaster. Users indicated that iCEMAS must have a platform to share knowledge with the public and with NSC members, lessons learned for disasters, and online links, such as video, relevant organizations, NGOs, experts, and government departments. A total of 95.8% of the respondents agreed that the system would improve current knowledge and information challenges. This information is shown in Table 8.

Next, structured interviews were conducted to investigate the critical success of KMS for EM. The results of our questionnaire for the research model are presented in Table 9.

The result in Table 9 is presented in a dichotomous form and indicates whether perceived influence of a specific variable exists. Data were collected from a five-point Likert scale questionnaire. All the variables presented in the theoretical framework were included. The columns represent the questions related to each variable whereas row represents the answers given by one person. A score of one implies a positive iCEMAS effect, whereas a score of zero implies a negative iCEMAS effect. In the following section, these results are examined in further detail.

4.4.1. System quality

Technological Resources (SQ1): A total of 79% of NSC emergency managers agree that NSC had the necessary technical resources to use KMS in the form of iCEMAS to support EM. iCEMAS was built with a minimal requirement for technical support. The system enables users to use its functions with minimal technical support service because it has simple interfaces with easy to manage features.

KMS Form (SQ2): All the emergency managers (100%) agreed that a web-based form of KMS such as iCEMAS can support the need of EM. iCEMAS can be easily accessed via web by using both PC and smart phones. Users prefer the online version because of the popularity and ubiquity of the Internet. Data rates for the Internet are extremely cheap, thus facilitating mobile computing. Furthermore, converting any document into web format is easy at the organizational level.

Level of KMS (SQ3): Of the emergency managers, 96% agreed that iCEMAS supported different levels in their organizations with fast and accurate information. Different levels may have different EM functions. For example, district and state levels feed data to the federal level. The

[4] SOP is standard operating procedures.

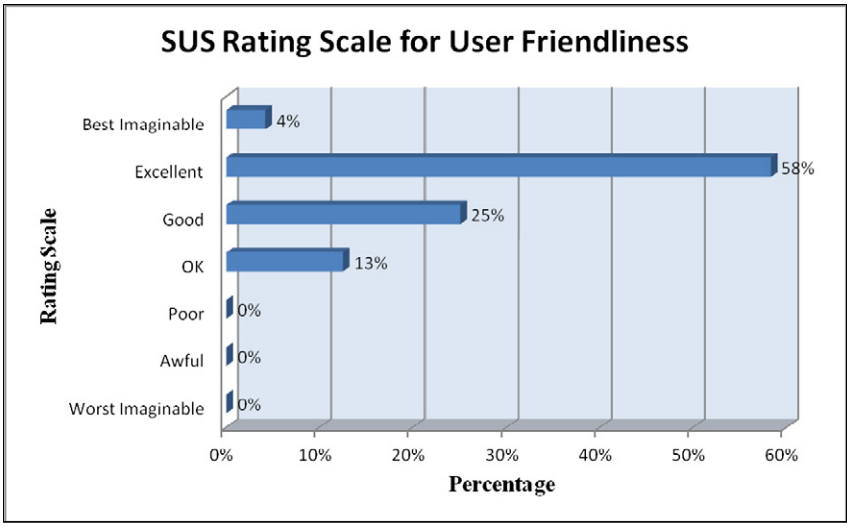

Fig. 8. SUS for user friendliness.

federal level then updates information, facilitates 3Cs to ensure proper control, and monitors discussions.

4.4.2. Knowledge quality

KM Strategy/Process (KQ1): iCEMAS enabled NSC officers to enhance their strategic planning process for teams involved via private group discussions. For example, when NSC officers are on a mission or program, officers can obtain information through iCEMAS from their headquarters in different states. Moreover, 92% of the officers agreed that iCEMAS can support different EM levels.

Richness (KQ2): A total of 96% of the NSC officers had positive impression on the role of iCEMAS toward providing sufficient knowledge on disasters by periodical reports, international information, and learning features. Games, videos, relevant links on conferences, books, journals, and external reports are regarded as rich knowledge that improves the quality of knowledge to support EM. Search functions for the database and the entire website provide flexibility and easy

Table 8
Addressing client's issues.

Issues faced by the client (from problem diagnosis)	Client goals (from problem diagnosis)	User requirements (from action planning)	System features (from action planning)	Extent of goal achievement
1. Communication, collaboration & coordination issues (3Cs)	Communication among the 3 different level (district, state and federal) needs to be improved for better control and command	1. Communication tool that is secured between all staff in NSC regardless of levels. 2. Communication with others such as government agencies, community and other stakeholders seamlessly 3. Group discussion with possibility to create private discussion	1. Members 2. Forum 3. Group Discussion 4. Social media: Twitter, Facebook 5. Email	**91.3%** of the respondents agreed that the system would improve the current challenges faced in terms of communication. (Question 1: Yes (70.8%) + Yes with additional factor (20.5%) = 91.3%)
2. Data management issues	Data regarding assets, drills, disasters, sop, reports, lessons learned must be available during all three stages of disaster	1. Easy access to records 2. Easy access to policies, rules and Acts 3. Easy to search for data	1. Assets table 2. Disaster table 3. Drills table 4. SOP list and links 5. Reports repository 6. Lessons learned table	**100%** of the respondents agreed that the system would improve the current challenges faced in terms of data management. (Question 2: Yes (87.5%) + Yes with additional factor (12.5%) = 100%)
3. Knowledge and information issues	Information and Knowledge about disaster planning and response need to be disseminated in integrated manner. There is a need for integrated platform to facilitate knowledge sharing	1. Platform to share knowledge with public and with NSC people 2. Lessons Learned for disasters 3. Online links – video, organizations, NGOs, Experts, Government Dept.	4. Games 5. Links 6. SOP 7. Lessons learned table 8. Knowledge socialization via forum 9. Event logs and analytics 10. Public announcement, news and posts	95.8% of the respondents agreed that the system would improve the current challenges faced in terms of knowledge and information issues. (Question 3: Yes (87.5%) + Yes with additional factor (8.3%) = 95.8%)

Table 9
Results of KMS success factors.

Respondent	Critical success factors																		Net impact	
	System quality			Knowledge quality			Service quality			Situational quality							Intent to use	User satisfaction		
	SQ1	SQ2	SQ3	KQ1	KQ2	KQ3	SeQ1	SeQ2	SeQ3	SitQ1	SitQ2	SitQ3	SitQ4	SitQ5	SitQ6	SitQ7	IU	US	NI1	NI2
Person 1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	1	1	1
Person 2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Person 3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1
Person 4	1	1	1	0	1	1	1	1	1	0	1	1	1	1	1	1	0	0	1	1
Person 5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Person 6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Person 7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Person 8	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Person 9	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1
Person 10	0	1	1	0	1	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1
Person 11	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1
Person 12	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Person 13	1	1	1	1	1	1	1	0	1	0	1	1	1	1	1	0	1	1	1	1
Person 14	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Person 15	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Person 16	0	1	1	1	1	1	1	0	0	0	1	1	0	1	0	1	1	1	0	1
Person 17	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Person 18	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Person 19	1	1	0	1	1	1	1	0	0	1	1	1	1	0	1	1	0	1	1	1
Person 20	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Person 21	0	1	1	1	1	1	1	1	1	0	1	0	0	1	1	1	1	1	1	1
Person 22	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1
Person 23	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Person 24	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Frequency	19	24	23	22	23	23	24	18	22	18	24	23	22	23	23	22	21	22	23	24
Percentage	79%	100%	96%	92%	96%	96%	100%	75%	92%	75%	100%	96%	92%	96%	96%	92%	88%	92%	96%	100%

1 = Positive effect of iCEMAS.
2 = Negative effect of iCEMAS.

information access. However, one of the officers mentioned that excessive information is overwhelming and distracts the focus of KMS from EM. Another top-level officer asserted that no information can be considered as insignificant for EM: that is information are important in the domain of EM.

Linkages (KQ3): In the survey, 96% of the NSC officers agreed that iCEMAS contained important links, such as links to disaster support agencies, welfare department, police department, and NGOs, that could be used as resources for EM. Links to new knowledge, useful websites, available internal and external expertise, and learning materials also add value to KMS.

4.4.3. Service quality

Management Support (SeQ1): All 24 NSC officers (100%) expressed that strong management support was critical for the success of iCEMAS as a KMS tool in NSC. NSC agreed that a large proportion of departmental co-workers would use KMS for EM, particularly the senior management comprised Secretaries and Assistant Secretaries of the NSC disaster division, who positively echoed and showed support for the KMS initiative at the departmental level. Given clear direction from the NSC headquarters, the state- and district-levels of NSC will cooperate and will provide support.

IS KM Service Quality (SeQ2): The results show that 75% of the NSC officers agreed that their IT teams could provide support for the use and maintenance of iCEMAS. IS KM services include ensuring system availability 24/7 and timely responses by qualified IS team members. KMS is designed to minimize unnecessary user effort. All changes can be completed via the dashboard by the manager controlling the data, information, and knowledge. Minimal help is required from the IT team.

User Organization KM Service Quality (SeQ2): According to the survey, 92% of the NSC officers agreed that KMS users will be supported with good service. The organization encourages knowledge sharing and dissemination. However, incentives, rewards, or policies on KM initiatives are lacking.

4.4.4. Situational quality

Complexity of Environment (SitQ1): The survey revealed that 75% of the NSC officers agreed that KMS in the form of iCEMAS would be able to provide support during complex environments such as disasters. A complex environment entails stressful, tense, time-constrained decision-making and the need to access information quickly. Hence, system simplicity and familiarity are important. iCEMAS provided these two criteria. Multi-party communication tools were also added because communication between multiple parties and adequate support is important in complex environments to ensure that lifesaving information and activities can be delivered promptly.

Cognitive Absorption (SitQ2): All (100%) of the 24 NSC officers agreed that KMS in the form of iCEMAS could improve cognitive absorption (remember, think, and reason) during stressful disasters; thus allowing users to handle EM situations better. The ability to think, remember, and reason is affected by disasters because of the pressure and time constraints posed by the situation. Hence, disasters affect the quality of decision making. A simple KMS that enables knowledge dissemination with fast access to current information will assist in improving cognitive absorption of the individual productivity level.

Situational Awareness (SitQ3): The survey shows that 96% of the officers agreed that KMS in the form of iCEMAS provided situational awareness on people and resources during disasters. Information on people can be easily accessed via the members by simple search. For example, if an expert is required, then the keyword, "expert" gather all experts from the database. Information on vulnerable locations, community and disasters are readily available, thus improving knowledge. Other information such as food supply, water, and shelter, could be sourced via forum communication with the relevant department. For instance, the welfare department will be contacted for food and water supply. The progression of any event can be monitored via frequent updates and community announcements. For example, information on evacuation progress and flood levels will improve situational awareness.

Rigidity of Response (SitQ4): A total of 92% of officers agreed that KMS in the form of iCEMAS reduced the rigidity of response because of the availability of various forms of support for EM. iCEMAS has an automated notification that facilitates the free exchange of information, assist in developing a comprehensive databank on expertise, and reduces the rigid use of existing procedures. A reduction in the rigidity of response will result in improved quality in EM initiatives and easy handling of both external and internal threats.

Discipline and Agility (SitQ5): A total of 96% of the officers agreed that KMS in the form of iCEMAS provided functions to organize their current and historical data during disasters. The database component of iCEMAS provides all historical and current information about disasters, drills, assets, lessons learned, and SOP. Experiences, actions taken and recommendations from disaster events are useful in the decision-making process of emergency managers.

Roles (SitQ6): A total of 96% of NSC officers agreed that KMS in the form of iCEMAS ensured that the appropriate parties had access to important information. The roles can be easily assigned or adjusted based on the new environment. This function is crucial for emergency management (Turoff et al., 2004).

Dynamic Response (SitQ7): A total of 92% of NSC officers agreed that KMS in the form of iCEMAS supported the dynamic response (well-trained teams, lessons learned, and regular tests) of a disaster. The regular use of iCEMAS will ensure dynamic response from the working team or the formation of new teams via trust. The provided communication systems improve the dynamic response.

4.4.5. User satisfaction (US)

A total of 92% of NSC participants agreed that because iCEMAS fulfills all four success factors (system, knowledge, service and situational), user satisfaction is high in terms of using the system for EM activities in NSC. The positive perception of the four qualities has a significant effect on user satisfaction.

4.4.6. Intent to use/perceived benefit (IU)

A total of 88% of NSC participants indicated their positive intention of using iCEMAS to support EM activities because these respondents anticipate that the system will improve their current state in terms of KM. The majority indicated that the system is simple and has an easy-to-use interface that required less effort to learn. The positive perception of the four qualities has a significant effect on intent to use.

4.4.7. Net benefit

Individual Productivity (NB1): A total of 96% of all NSC respondents agreed that the use of KMS in the form of iCEMAS improved individual EM productivity.

Organizational Productivity (NB2): All (100%) NSC respondents agreed that the use of KMS in the form of iCEMAS improved organizational EM productivity.

4.5. Prototype successfulness

Reflection marks the final stage of action research. During this stage, the results of all the phases were analyzed, triangulated and synthesized for knowledge contribution and recommendation for future work. Baskerville (1999, pg. 24) categorized a prototype as a success in his project presentation. He indicated that the prototype can be considered a successful or unsuccessful based on the points in Table 10. The prototype KMS designed for EM was well received by the Disaster Division of NSC. In addition, top-level officials gave excellent feedback on their overall impression of the system. The following are some of the statements from the top officials in NSC:

Table 10
Prototype successful according to Baskerville (1999, p.5).

Prototype is "success" if it	Agree (✓)/disagree (X)	How did the iCEMAS prototype fulfilled the prototype 'success' criteria?
• Revealed the design feasibility	✓	The system provided feasible design that was simple and easy to modify. The user interface and database designs were uncomplicated. All respondents fully agreed that the system provided a positive impression during initial viewing. Respondents' statement such as the following affirmed this finding: "I am impressed. It can improve knowledge with all information provided" "The view and all of the functions because it looks very tidy and easy" Respondents were impressed and the system improved their knowledge with the information provided. They also stated that they liked the functions, design, and user-friendliness of the system.
• Users enthusiasm, their control over system design elements	✓	The system provided easy control over system design elements. For example, the dashboard of WordPress content management system contains mechanisms that are easy to use, manipulate, and control. The enthusiasm in using the system were captured by the system usability score (SUS). A total of 79% (19) of the respondents were very confident in using the system as indicated through item 9 of the SUS (i.e. I felt confident in using this system).
• Rapid progress that please the management	✓	The system was developed by adopting Rapid Application Development methodology that involves user participation. NSC officers participated in the development process by providing suggestions and feedback at every stage of development. This involvement helped improve the acceptance of NSC of the system.
• The deadline effect of large specification	X	System development did not require considerable specifications. User requirements were collected by open-ended questions, and interview sessions. The majority of requirements were provided to the system with some limitations. No sizable specifications or deadlines were issues on the systems.
• Process of entering real data into prototype's database was challenging	X	The data entered in the database were based on simulated data. Real data only involved communication data such as forum content.
• Users unveiled their disagreements with the designers	X	Most of the respondents revealed satisfaction with the system design. Except for some security concerns on misuse within forum discussions, no major concerns existed for the system design.
• Parallel application prototype added	X	No parallel application prototype was employed in this study.

"I am impressed. It can improve knowledge with all information provided"

"It helps to open up discussions, feel how we synergize the thoughts into meaningful and

"Good portal for information sharing which is essential in disaster management."

"Good system with clear interface of easy-to-use navigation."

Given the above statements and descriptions, the KMS prototype designed to support EM in NSC is successful.

5. Discussion

We have initiated this study to fill the gap in literature on applied KMS for EM as well as to improve the current challenges faced by emergency managers in Malaysia, namely the NSC. This research aims to ascertain if the KMS success factors can be effectively used to design a KMS for EM. Two objectives were devised to guide this research: (1) to develop a model that explains and guides effective design considerations for KMS success to support EM, and (2) to develop and implement a web-based KMS prototype to address the 3C,[5] information visibility, and information/knowledge sharing and dissemination challenges faced by the NSC and the community in relation to its EM efforts toward improving disaster resilience. The expected outcome of this objective is a prototype that addresses the 3C, data management, and information/knowledge sharing and dissemination challenges faced by the NSC.

The first objective is regarding the application and use of the KMS success model to guide the design decision of the proposed system (i.e. iCEMAS) in an institutional context (i.e., NSC) to support EM efforts. The KMS success model by Jennex and Olfman (2006) was suitable for guiding the design decisions of a simple KMS. The KMS was applied in the EM domain. EMIS implies that disaster situations have unique characteristics (Xu et al., 2008; Turoff et al., 2004, French and Niculae, 2004; Raman et al., 2006, 2010; Snowden, 2002). A complex disaster situation involves role changes (Turoff et al., 2004; Snowden, 2002), new responsibilities, interaction with many agents (Snowden, 2002), and ever changing causes and effects (Snowden, 2002). A disaster situation is also marked with unpredictability, uncertainty, and lack of coordination, in a stressful environment. These characteristics make the decision-making process complex. Unique disaster characteristics were the key in discovering success factors that must be considered in designing a KMS for EM. The search for relevant disaster-related success factors revealed a new dimension, namely situational quality (SitQ). We coined the term "Situational quality". Thus, a situational perspective was recommended to understand and develop information systems that are socio-technical in orientation rather than scientific. The researcher added SitQ as a critical dimension to the existing three dimensions proposed by Jennex and Olfman (2006), i.e. system quality (SQ), knowledge quality (KQ), and service quality (SeQ). The effects of the four dimensions (i.e. SQ, KQ, SeQ, and SitQ) and their unique variables were tested to affect net benefits in individuals and organizations.

This research proposes a KMS that can effectively support group planning and respond to complex, dynamic, and stressful situations such as disasters. The literature on applied and conceptual EMIS discusses these factors. Seven variables were included in SitQ dimension: the complexity of the environment, dynamic response, situational awareness, roles, response rigidity, cognitive absorption, and discipline and agility. These variables were tested during both Stage 2: Action Planning (pre-system) and Stage 4: Evaluation (post-system). The results were consistent with the literature.

[5] 3Cs refers to Communication, Collaboration and Coordination.

5.1. Evaluating the feedback

Pre-system perception and post-system evaluation during Stage 2: Action Planning and Stage 4: Evaluation, respectively, indicated that NSC emergency managers had strong positive views toward the KMS for EM based on SitQ variables. The former secretary of the Disaster Division of NSC Malaysia, expressed a positive feedback during the post system evaluation, in which he indicated that the system has "user-friendly homepage".

The Secretary of the Disaster Division of NSC, Prime Minister's department observed that the system is a "simple and straight forward approach".

The following statements of other emergency managers proved the complexity of the environment and design influence of the KMS for EM in this study:

"Yes, because the system looks very organized and structured. However, there are so many elements in response that are in need such as information dissemination, reporting disaster up to the top level and providing GIS/GPS usage." (NSC, Disaster Division, Federal Level).

"Easy access to all the available information. Clear interface" (NSC, Disaster Division, Federal Level).

"Clear interface, easy to use navigation, clear information." (NSC Officer at District Level).

"Easy to use and very informative" (NSC Officer at District Level).

"Simple version, eye pleasing" (NSC Officer at State Level).

Following the above statements, the NSC emergency managers generally confirmed that the simple interface and functionalities provided in the system reduced the difficulty in communicating, and sharing knowledge and information with other agencies. Hence, considering the complexity of the environment is important for a KMS for EM. The Secretary of the Disaster Division of NSC further commented that:

"It can help in capturing relevant information from public to enhance the data already available".

This statement was echoed by the federal level director for Disaster Division in NSC by stating that the system aids in the effective accomplishment of tasks. One of the state-level Secretaries of NSC supported this statement and emphasized that the ability to have a close group discussion is key for any complex situation. Another federal-level NSC Assistant Secretary in the Disaster Division supported the statement and said that the system can solve current challenges because it has links to agencies and fulfills user satisfaction.

5.2. Evaluating KMS-EM using situational quality variables

We posited that a KMS that is designed to support EM must consider situational awareness imperatives. The availability of information on people, locations, disasters, assets, and vulnerabilities in the system was well received by NSC emergency officers. The result was consistent with the SA imperatives that were described on the availability of disaster information by Ashish et al. (2008), Madey et al. (2007), and Harrald (2006). SA proved to be relevant in providing lifesaving knowledge. This knowledge includes lessons learned and information on emergency responses (Carver and Turoff, 2007), in addition to the comprehension and interpretation of information into action plans (Yang et al., 2009).

The emergency managers in the NSC were provided with the ability to perform effectively by ensuring that SA was well articulated through the KMS model (Madey et al., 2007). The positive effect of SA was well supported by this research as recommended by Harrald and Jefferson (2007) to develop a system for EM with enhanced shared SA without impending organizational agility.

The complexity of environment refers to the characteristics of unpredictability, time pressure, media response and interactional, operational demand, and inter-agency conflict, and terminology. These characteristics influence the situation under an EMIS (Jennex, 2004; Bellardo et al., 1984; Paton and Flin, 1999). The complexity of environment can be supported by designing a simple KMS that uses an extremely simple interface; provide learning facilities on the past, present, and forthcoming disasters; is able to designate changes in priorities; has the ability to filter, and provides delivery options (Turoff et al., 2004; French and Niculae, 2004).

Cognitive Absorption (CA) is another key variable in SitQ. CA must be considered when designing KMS for EM. CA refers to the psychological state of a person who is deeply involved in an activity and has the ability to think, remember, and reason. The results of the present research were consistent with those of Prasanna et al. (2011), who developed a prototype system for fire fighters. According to Prasanna et al. (2011), a system that is used during stressful situations results in decision- making errors. Hence, a KMS designed for EM that considers CA in its design features will increase cognitive absorption and lessen threat rigidity (Plotnick and Turoff, 2011). This study had tested and confirmed that extremely simple interface increased cognitive absorption, thus decreasing decision-making errors (Turoff et al., 2004) and reducing stress levels (Sattler, 2000; Paton et al., 2010; Kassam et al., 2009; Agarwal and Karahanna, 2000).

Discipline and Agility (DA) are critical in the situational dimension. Well-organized disaster memory with historical data and experiences ensure the discipline factor within KMS for EM (Harrald, 2006; Boehm and Turner, 2004). A KMS is considered agile if an organized disaster memory exists within the complex environment, such as a disaster and helps unexpected decision-making efforts. This study enabled free access to all information between various stakeholders of disaster situations via communication tools, and coordination and collaboration features. The results revealed that a KMS can effectively be designed for EM by making disaster memory tools and aids available (Turoff et al., 2004, 2008).

Roles (R) was suggested by Turoff et al. (2004, 2011) as an important feature of any emergency system. A KMS for EM must incorporate features that enable role changes and allow people to access changes based on the situational requirement. The ability to change roles and responsibilities is crucial in the situational dimension for the facilitation of dynamic roles and formation of teams. Turoff et al. (2004) suggested 12 fundamental roles. However, this study managed to include at least 10 roles in the KMS designed for EM: (1) report and update situation; (2) analyze situation; (3) edit, organize and summarize the information; (4) maintain resources; (5) acquire more or new resources; (6) alert all on a need-to-know; (7) oversight review, consult, and advise; (8) assign roles and responsibilities when required; (9) coordinate among different resource areas; and (10) priority and strategy setting.

Rigidity in response (RR) is considered the increased reliance and rigid use of existing procedures; thus translating decreasing participation, and workforce (D'Aunno & Sutton, 1992). Turoff et al. (2004) suggested that the provision of access and free exchange of information reduce rigidity in response. Through iCEMAS, this study provided the most relevant information for emergency responses, SOPs, lessons learned from past disasters, and actions taken using an extremely simple interface. When emergency managers have ubiquitous information, RR is reduced. This condition was evident during the simulation session that required the emergency managers to access information from the prototype KMS. The system provided automated notifications and free information exchanges, as well as facilitated active and enhanced mindfulness as suggested by literature (Plotnick and Turoff, 2011; D'Aunno & Sutton, 1992; Agarwal and Karahanna, 2000). This result is consistent with past research on RR.

Dynamic Response (DR) refers to well- trained and experienced working teams, the implementation of regular tests, the availability of communication systems and knowledge on lessons learned, and the effect of groups of people. DR was considered in designing a KMS for EM. Regular system use and communication among disaster actors are crucial in building trust among individuals in EM. This study included DR features in the prototype and tested their influences toward the creation of SitQ. The results of the current research were consistent with the literature.

This study retained all the dimensions and factors of the KMS Success Factors Model by Jennex and Olfman (2006). The model has not been tested in a disaster domain prior to this study. This study is the first to test this model in the disaster domain and the first to determine that all dimensions, namely, System Quality (SQ), Knowledge Quality (KQ), and Service Quality (SeQ) along with user satisfaction (US) and intent to use (IU) can positively affect Net Benefits (NB) for a KMS. The model provided a strong foundation in an underlying model to enhance SitQ and ascertain that KMS for EM could be effectively designed. The results of this research in Chapters 4 and 5 clarified that all dimensions work well toward a successful KMS for EM. The results were robustly supported by literature on KM and KMS.

The second objective of this study is regarding the development, testing, implementation, and evaluation of a web-based KMS prototype to support EM in the NSC, and ascertain the success factors in a simulated scenario. This objective was achieved by developing a KMS prototype, namely, iCEMAS. The web-based KMS was developed to support three major challenges in EM: (1) 3Cs, (2) data management, and (3) information/knowledge sharing and dissemination. The system was tested in a simulated environment by creating a disaster scenario within a meeting room in the NSC to address a disaster situation. The time used in gathering information and knowledge by using iCEMAS with KMS and without KMS was recorded. The result presented revealed that the NSC had access to information such as lessons learned, and database on assets, experts, people, drills, disasters, reports, and SOPs. Emergency managers are required to make phone calls to various government agencies to obtain information. Recorded information is usually kept a manual paper-based format. In terms of response, the NSC had the ability to respond faster and more efficiently with KMS than with the current methods. The developed prototype by using open source software proved to be an efficient tool in facilitating and solving the current challenges faced by the NSC for EM. However, the real challenge of implementing KMS in the NSC requires a change in the mindset and the consideration of organization cultural factors and the bureaucratic mechanism involved in implementing the IS solution.

This study successfully identified success factors in the support provided by KMS to EM based on the unique characteristics of disaster situations. SitQ, along with all the KMS success factors proposed by Jennex and Olfman (2006) was used to guide design decisions. A prototype was developed based on the enhanced KMS success factor model for EM by using open source software tools. This study used an AR approach in testing KMS for EM. The prototype was evaluated by using a simulated scenario and evaluation sessions involving multi-methods. The results indicated that a KMS can be designed to support EM by using the proposed framework. The three challenges faced by NSC were successfully managed by the change in this AR study. Disaster situations possess unique characteristics. Thus, the results of this study might not be suitable because this study attempted to solve current problems by using AR. Nevertheless, the proposed framework might be suitable or could be generalized to similar complex, volatile, ad hoc, and stressful situations.

This study highlighted the knowledge gap concerning the applied KMS for EM. In the past, most IS that is built for EM such as decision support systems, expert systems, management information systems, or database systems, were highly technical, system-oriented or model-based. Prominent researchers have mentioned that systems that are intended for EM should not be purely model-based or technical-oriented but should be situation-based because disaster situations are unique by nature (Xu et al., 2008; Turoff et al., 2004; French and Niculae, 2004; Raman et al., 2006, 2010; Snowden, 2002). Generic systems are unsuitable for disaster situations because these systems do not consider the unique characteristics of a disaster situation. Ill-suited systems will incur sizable losses in serving the community of practice in terms of sharing and dissemination of lifesaving knowledge (Huber, 2001). Complex disaster situations involve role changes (Turoff et al., 2004; Snowden, 2002), new responsibilities, agent interactions (Snowden, 2002), and changing causes and effects (Snowden, 2002). Disaster situation also has unpredictable, uncertain, stressful, and unforeseen effects (Bui and Sebastian, 2011). These factors complicate the decision-making process. Hence, KMS will fail if the system does not adapt and evolve to suit situations that are highly uncertain and constantly changing (Malhotra, 2002).

A detailed literature review was conducted in this study to investigate the unique characteristics of disasters and the difficulties that these disasters pose. Thus, we introduced a prototype KMS that used SitQ along with other KMS success factors proposed by Jennex and Olfman (2006). The prototype aims to ensure that the system was less technical-oriented but was highly flexible and enabled knowledge to flow among experts and disaster actors within unique situations such as disasters. A better understanding of the situational perspective will allow the development of IS that are situation-oriented rather than the model- or technical-oriented.

The research contributed considerations for the design of KMS for EM. A well-designed KMS can bring a group of experts and the community together; thus offering an effective platform for sharing knowledge on prior experiences and impending EM issues. The resulting knowledge-base can be used to aid timely response in disaster situations. Although the idea of using a KMS to support EM has attracted some degree of interest in the last decade, the concept of applying situational qualities as key design consideration for KMS in supporting EM is arguably new. In the past, KMS was predominantly managed by a structure with manual processes, model-based, and technical orientation; the contemporary literature/projects on KMS suggest that KMS for EM can be designed to offer more robust and flexible creation, storage, sharing, and dissemination of disaster-related knowledge.

5.3. Limitations and future recommendations

Several limitations are noteworthy for this study. First, the research model presented in this study may not be suitable or generalized for other social settings that implements KMS. This research aims to solve the problem of the client, thus the generalization of the result to another research domain is not the main concern. Nevertheless, the proposed framework might be suitable or could be generalized to similar complex, volatile, ad hoc, and stressful social settings.

The client for this research is a government body with the highest security and safety agenda for the country. EM is a national security issue. Hence, the researcher experienced difficulty in obtaining access to officials, observing organizational culture, and processing and assessing the effects of change that the agent introduced to reduce problems.

The action research method is not without challenges. Problems faced during the course of this study include the following:

- Obtaining the buy in initially from the State EM team - we had to develop a test case and show them a proof of concept before we were allowed to work with them;
- Delays in feedback from the client (NSC Selangor) during the flood that hit the Northern States. The delays are due to most officials being away and our project was somewhat delayed - key players and decision makers were not available;
- Access to confidential data - to ensure a fully featured EM System, cross sharing of knowledge among various stakeholders is necessary. In our case, similar to the case of most government-linked projects, obtaining information and knowledge across different stakeholders was an issue.

Finally, the research could not include the spatial and remote sensing data, despite the users' preference of these forms of data. These features are beyond the scope of this research as they involve the engineering and computer science fields.

Several options are feasible for future work in examining the design considerations and implications of a KMS for EM. KMS is developed to support EM, specifically to improve resiliency level requirements to develop a system that is compatible with mobile devices and smart alerting systems. This system will aid in the swift response by both responders and communities affected by disasters. Future work should also study other key variables that are related to situational awareness, trust, privacy, security and resilience. Lack of trust, privacy and security are among the prominent barriers for system usage in EM. Future work may focus on how to overcome these problems.

6. Conclusion

The NSC was pleased with iCEMAS. The system was recognized as a one-stop center for NSC to communicate, coordinate, and collaborate with community and supporting agencies. NSC officers also agreed that iCEMAS can solve the data management, knowledge-sharing, and dissemination issues. From a theoretical stance, the study findings also confirmed that all the factors in the revised KMS success factor model (including the new dimension—situational quality) were vital in considering the design of a KMS to improve disaster resilience. This study has contributed toward bridging the gap between the government agency and the vulnerable community for disaster resilience efforts.

In summary, this study has achieved the two goals of action research. From a practical lens, the client organization indicated that iCEMAS has solved the current challenges faced by the NSC regarding EM. Theoretically, this study has attempted to bridge the scientific gap between applied KMS and EM toward improved disaster resilience. This study offered the EM and KMS communities a series of research ideas to advance in this field. Thus, a scope for more research in this area is also presented.

An action researcher aims to solve a real world problem in an organizational context (Baskerville & Wood-Harper, 1998). The major contribution of this study is the implementation and application of a web-based KMS within the NSC to support the EM efforts of the organization. Specifically, this web-based KMS improves (i) 3Cs among disaster community of practice; (ii) data management which provides critical data, information, and knowledge visibility to emergency managers for improved decision making and control; and (iii) lifesaving information, knowledge sharing, and dissemination among NSC affiliates and supporting agencies. The overall impression by NSC top officials regarding the system are as follows:

> "I am impressed. It can improve knowledge with all information provided".

> "It helps to open up discussions, feel how we synergize the thoughts into meaningful and doable action plans could be one area one needs to give deeper thought on it."

> "Good portal for information sharing which is essential in emergency management."

> "Good system with clear interface of easy-to-use navigation."

Given the above statements and description, the prototype designed to support EM in the NSC is well received and successful. In terms of response time, the NSC had the ability to respond faster and more efficiently with the iCEMAS than with the current methods. The system proved to be an efficient tool in facilitating and solving the current challenges faced by NSC for EM. The iCEMAS was designed and developed for the NSC to communicate, coordinate, and collaborate with the community and supporting agencies to assist EM efforts and to apply the KMS success model. The concept of KMS for EM is rather new to the NSC. However, NSC emergency managers trusted that the proposed KMS which considered situational qualities with other KMS success factors can solve current challenges in EM. Theoretically, the system provided evidence supported by the KMS critical success factors for EM. The evidence was reflected in the design considerations of KMS for disasters. The case study confirms that KMS can be effectively developed to support EM in Malaysia by considering situational quality in the design.

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Appendix A. Measurements of success factors and post-system evaluation questions

The Measurements of Success Factors.

Success factor	Measures (item num.)	Items	Sources
SF1: System quality	1. Technological resources (1–5) 2. KMS form (6–9) 3. Level of KMS (10 — 12)	1. Ability to use word processing, spreadsheets, and presentation tools are important technical resources for quality KM system for disaster. 2. Ability to use hardware, software, network, and database of computing systems are important technical resources for quality KM system for disaster. 3. We have the necessary resources to develop KMS to support the EM 4. We have the necessary resources to update EM to support the EM efforts 5. We have the necessary resources to maintain KMS to support the EM efforts 6. More information about the EM activities at our organization can be converted to Web format. 7. Knowledge from individuals can be made available and shared online 8. Knowledge from EM from relevant groups can be made available online 9. Knowledge about EM can be automated, shared and retrieved from a single web interface 10. The system can provide fast access time to retrieve knowledge. 11. The system can be accurate, reliable, easy to use, and available to users. 12. The system can provide functions at different level such as district and state level users.	Chui, 2009; Raman et al., 2006; Jennex and Olfman, 2006; Raman et al., 2006
SF2: Service quality	1. Management support (1–5) 2. IS KM service quality (6–10) 3. User KM service quality (11–15)	1. It is important that the senior management of the department to be helpful in introducing the KMS to all 2. It is important that the boss to be very supportive of the KMS for disaster use for users' job. 3. In general, the organization must support the introduction of the KMS for disaster. 4. Clear direction from top management is needed. 5. Top management support is very critical to the success of KMS implementation. 6. IS team should provide responsive service quality to KMS for disaster users. 7. IS team should competent to provide quality service to KMS for disaster users. 8. KMS has to be accessible to all the staff involved. 9. Support and help-desk should be provided 10. The system has to be available to user 24/7. 11. Poor service quality will lead to ineffective use of KMS for disaster. 12. Organization should provide quality service for users to use KMS for disaster effectively 13. I welcome the idea of being trained in using a KMS to support EM 14. We have the necessary support for quality service for users to use KMS for disaster frequently and efficiently 15. Individual should learn faster with the support of KMS.	Thompson et al., 1991; Jennex and Olfman, 2006
SF3: Knowledge quality	1. KM strategy/process (1–3) 2. Knowledge richness (4–9) 3. Linkages (10–14)	1. A KMS should make EM strategy clear. 2. A KMS for EM should enhance the strategic planning process for teams involved in EM 3. KMS have the ability to manage the collection, synthesis, analysis, and internal and external distribution of information is established 4. The system should provide sufficient knowledge on disasters to users 5. The system should provide reports just about exactly what is needed by users	Jennex and Olfman, 2006; Raman et al., 2006; Rockhart & Bullen, 1981; Caralli et al., 2004; Doll & Torkzadeh, 1988

Appendix A. (*continued*)

Success factor	Measures (item num.)	Items	Sources
		6. A KMS should provide relevant information for staff involved in EM 7. A KMS should provide timely information and knowledge for staff involved in EM 8. A KMS able to search for information needed 9. A KMS should provide relevant information for staff involved in EM 10. A KMS should provide linkages to other useful websites and information 11. A KMS should provide linkages to both internal and external expert (expert locator function) 12. The system will be successful if it provides useful links of knowledge on disasters 13. The system will be successful if it provides listings of expertise available 14. The system will be successful if it provides listings of resources available	
SF4: Situational quality	1. Complexity of Environment (1–5) 2. Cognitive Absorption (6–10) 3. Situational Awareness (11–14) 4. Rigidity of Response (15–21) 5. Discipline & Agility (22 − 23) 6. Roles (24–25) 7. Dynamic Response (26–30)	1. EM is a stressful situation, therefore a KMS for EM will provide easy accessibility to timely information, thus reducing the stress level 2. EM involves time pressure, therefore a KMS for EM will provide real time information at fast speed 3. Disaster event is unpredictable, therefore, a KMS for EM that is used frequently for familiarity is expected to help during complex environment 4. EM involve multiple individuals and organization, therefore, a KMS for EM with multi-party communication tools will reduce the complexity of environment 5. EM involve unexpected and unique problems, therefore, a KMS will provide adequate information of needed expertise to solve the unexpectedness in complex environment. 6. KMS should increase cognitive absorption by providing involvement in activities such as responding to threat 7. KMS should increase cognitive absorption with features that allow users to effectively muddle through and make sense of the reality they face. 8. KMS should increase cognitive absorption with features that enable focused immersion such as being totally absorbed or immersed in whatever you are doing. 9. KMS should increase cognitive absorption with features that enable you to enjoy using the system 10. KMS should provide information about people - their vulnerabilities, location, demographics will improve situational awareness 11. KMS that provide information about resources (food, water, shelter) will improve situational awareness 12. KMS that provide information about progression of the event and activities (plume spread, storm track, evacuation progress) will improve situational awareness 13. Situational awareness is obtained and shared across distributed organizational network using KMS 14. KMS should reduce Rigidity of response through automatic notifications and free exchange of information with expertise 15. KMS should reduce Rigidity of response through comprehensive expertise databank so that they can be recognized and reached when needed. 16. KMS should reduce Rigidity of response by increased participation to support EM 17. KMS should reduce Rigidity of response by less reliance on rigid use of existing procedures to support EM 18. KMS should reduce Rigidity of response by anticipating and handling the external threat such as competition between organizations or units of an organization in a crisis 19. KMS should reduce Rigidity of response by anticipating and handling the internal threat such as trust and team cohesion within newly formed team 20. KMS should reduce Rigidity of response by improving cognitive absorption of individuals that s/he feels less cognitive burden, thus reduces the restriction of information 21. KMS should reduce Rigidity of response by encouraging mindfulness. If one is mindful, they have attention to detail. 22. KMS should provide a well-organized memories, history, and experience to support discipline elements in EM 23. KMS should provide avenue to apply memory and history to adjust to new environments to react and adapt, to take advantage of unexpected opportunities	Self-deviced items based on: Turoff et al., 2004, 2008, 2011; Jennex, 2007; Raman et al., 2006; Plotnick and Turoff, 2011, Agarwal and Karahanna, 2000; Ashish et al., 2008; Yang et al., 2009; Rockhart & Bullen, 1981; Rockhart, 1979; Caralli et al., 2004; Harrington et al., 2002; Harrald, 2006; Boehm and Turner, 2004; Turoff, 2002; Mayer, 2002; Bellardo et al., 1984 Modified Questions of Saade & Bahli, 2005

(continued on next page)

Appendix A. (*continued*)

Success factor	Measures (item num.)	Items	Sources
		24. KMS enables roles to make sure that the appropriate people had access to the information that they needed 25. KMS would support dynamic forming of teams based upon the roles needed for the situation. 26. KMS should improve the dynamic response of working team 27. KMS should improve the dynamic response by well trained and experienced team 28. KMS should improve the dynamic response of communication system 29. KMS should improve the dynamic response of the impacts of collectives of people 30. KMS should improve the dynamic response of lessons learned	
SF5: Intent to use	Intent to use/perceived benefit	1. Assuming that I am given access to the KMS, I intend to use it. 2. I will recommend other people to use it after my interaction with the KMS. 3. I intent to use as the use of the features such as event calendars, alert and KM chat team are beneficial for productivity of users' 4. I intent to use as the use of a KMS for EM should reduce the time needed for users' job responsibilities 5. I intent to use as the use of a KMS for disaster should increase the quality of output of users' 6. I intent to use as the use of a KMS for disaster should increase the effectiveness of performing job tasks of users' 7. I intent to use as the use of a KMS for disaster should increase the quantity of output for the same amount of effort of users'	Thompson, Higgins, & Howell, 1991
SF6: User satisfaction	1. Content (1–5) 2. Accuracy (6–7) 3. Format (8–10) 4. Ease of use (11 − 13) 5. Timeliness (14–15)	1. I perceive that I will be satisfied as KMS should provide correct content. 2. I perceive that I will be satisfied as KMS should provide the information content meet my needs. 3. I perceive that I will be satisfied as KMS should provide sufficient information. 4. I perceive that I will be satisfied as output from KMS will meet my needs. 5. I perceive that I will be satisfied as KMS will give me the right amount of information for my needs. 6. I perceive that I will be satisfied with the accuracy of KMS. 7. I perceive that I will be satisfied as KMS should provide accurate information. 8. I perceive that I will be satisfied as information presented in KMS will clear. 9. I perceive that I will be satisfied with the layout of the output. 10. I perceive that I will be satisfied with how the information will be presented to me. 11. I perceive that I will be satisfied as KMS will be user friendly. 12. I perceive that I will be satisfied as KMS will be easy to use 13. I perceive that I will be satisfied as KMS will enable me to do what I want it to do. 14. I perceive that I will be satisfied as KMS will allow me to get the information I need in time. 15. I perceive that I will be satisfied as KMS will provide up-to-date information.	9 items by Doll & Torkzadeh, 1988 - End user satisfaction; 6 items from Chin & Lee, 2000, End user satisfaction

Post-system evaluation questions.

Focus	Items
A. General feedback and overall impression of the system	1. What was your immediate reaction when you were first introduced to the systems? 2. Do you think that the system can assist EM efforts? Why? 3. What aspect of emergency planning do you think the system can help us achieve?
B. System specific questions	4. What did you like about the system? 5. What aspects of the system were you not comfortable with? 6. What other aspects should the system include?
C. Extent of goal achievement	7. Can the system help us improve communication between state office, the various districts and entities involved in EM? Why? 8. Do you think that the system will be useful to capture knowledge/information about EM? 9. Can the system allow people involved in EM to share knowledge/information with one another? Why?
D. Extent of solving current challenges in NSC	10. Can the system improve the current challenges faced by NSC in communication and coordination that causes inefficient order and control in EM efforts? 11. Do you agree that the system will improve the current challenges faced by NSC between all departments in terms of standard rules and policies in handling disasters that are still lacking, overlapping and unclear? 12. Can the system solve the problem of finding information on assets and experts for EM?

Appendix B. Useful details on applied EMIS past published studies

Summary of applied EMIS in the last two decades (1991–2011).

No.	Authors (year)	Name of the EMIS	Indicated and used KM concept for EMIS	Description	Emergency management focus	Method	System developed by author	System being studied by author
1	Aedo, et al. (2006)	ARCE		Web-emergency MIS	Web based system	Model based	0	1
2	Aziz, et al. (2009)	RFID		Building assessment system	response and recovery	Scenario-based	1	0
3	Bharosa & Janssen (2010)	CEDRIC	✓	Web- application for information sharing	Crisis response	Case study	1	0
4	Bond et al. (2007)	PPMS + RT		GPS based monitoring system	Prevention preparedness	Unclear	1	0
5	Büscher et al. (2009)	Overview		PalCom-enabled system	Virtual teamwork	Experiment based	1	0
6	Campbell & Weaver (2011)	Virtual globe		Role playing games	Hospital evacuation	Case study	1	0
7	Canós et al. (2011)	ShyWiki	✓	Hypertext spatial media	Emergency response	Case study	1	0
8	Caragea et al. (2011)	EMERSE	✓	Emergency response	Emergency response	Experiment based	1	0
9	Catarci et al. (2011)	WORKPAD		Process management system	Emergency response	Lab test	1	0
10	Chen & Dahanayake (2009)	PMISRS		Personalized multidisciplinary information seeking and retrieval service	Emergency response	Service-oriented	1	0
11	Chen et al. (2011)	Integrated components		RFID tags over mobile devices	During disaster	Field test	1	0
12	Chiu et al. (2010)	DNRAS	✓	Notification and resource allocation	Notification	Case study, Design	1	0
13	Dalal et al. (2011)	ExpertLens		Distribution group decision support	Communication	Delphi method	1	0
14	Molka-Danielsen & Chabada (2010)	Second Life™		3D multi user virtual environments	Evacuation, training	Case study	0	1
15	Dilmaghani & Rao (2007)	RESCUE		Wireless Ad hoc mesh network	Communication	Field test	1	0
16	Fedorowicz & Gogan (2010)	BioSense	✓	Detection tool for bio-terror attacks	Bio-terror surveillance	Case study	0	1
17	Becerra-Fernández et al. (2008)	vEOC using VRML97	✓	Collaborative multi-user	Emergency response systems	Prototyping	1	0
18	French et al. (2009)	ThinkTank		GroupThinks	Collaboration	Experiment based	0	1
19	Fruhling et al. (2006)	STATPack	✓	Support distributed laboratories	Preparedness	Action research	0	1
20	Goulart et al. (2010)	Next Generation-9-1-1		Real-world systems, spatial databases	Emergency call	Experiment based	0	1
21	Howe et al. (2011)	Social media		Collaboration system	Collaboration	Action research	0	1
22	Lijnse, et al. (2011)	iTask system		Workflow management systems	Search and rescue	Case study	0	1
23	Majchrzak et al. (2011)	TN		Geographically enabled DSS	Traumatized patients	Design science	1	0
24	Marrella et al. (2011)	WORKPAD		Process management system	Response	Lab test	1	0
25	McCarthy et al. (2008)	Expert systems		Spartial DSS, Expert systems	Monitoring and detection	Experiment based	1	0
26	McGuirl et al. (2009)	Imaging		UAV	Incident command center	Field test	1	0
27	Muhren et al. (2009)	MS Groove	✓	A peer to peer software system	Humanitarian response	Case study	0	1
28	Murphy and Jennex (2006)	PeopleFinder, ShelterFinder	✓	Emergency systems	Crisis response	Case study	0	1
29	Netten et al. (2006)	TAID		Task-adaptive information distributor	Dynamic collaborative	Experiment based	0	1
30	Panitzek et al. (2011)	MIT Roofnet		Access points of wireless mesh	Communication	Case study	0	1
31	Plotnick et al. (2008)	Wiki		E-communication and collaboration	Response	Case study	1	0
32	Prasanna et al. (2011)	Prototype		Prototype for situation awareness	Fire response	Prototyping	1	0
33	Raman et al. (2010)	TikiWiki	✓	Wiki-based KMS	Emergency response	Action research	1	0
34	Saoud, et al. (2006)	SimGenis		Agentbased simulation	Rescue plans	Field test	1	0
35	Schoenharl et al. (2006)	WIPER		Wireless phone-based emergency response (WIPER) system.	Emergency response	Not clear	1	0

(continued on next page)

Appendix B. (*continued*)

No.	Authors (year)	Name of the EMIS	Indicated and used KM concept for EMIS	Description	Emergency management focus	Method	System developed by author	System being studied by author
36	Shaluf & Ahamadun (2006)	TEES	✓	Expert system using xCLIPS	Decision support	Mixed method	1	0
37	Smirnov et al. (2011)	DSS	✓	Knowledge-based Intelligent DSS	Coordination	Case study	1	0
38	Stojmenovic et al. (2011)	Prototype		Decision support systems	Decision support	Prototyping	1	0
39	Tatomir et al. (2006)	Prototype		Mobile AdHoc network	Medical coordination	Prototyping	1	0
40	Tecuci et al. (2007)	Disciple-VPT	✓	A library of virtual planning experts	Training	Field test	1	0
41	Thomas et al. (2009)	EVResponse	✓	GIS-based response management	Notification	Design science	1	0
42	Toomey et al. (2009)	Geospatial tools		Geospatial tools	Emergency management	Action research	0	1
43	Trancoso et al. (2011)	OS		Integrated operational system	Early warning system	Case study	0	1
44	Turoff et al. (1993)	EMISARI	✓	Distributed group support systems	Decision support	Case study	0	1
45	Turoff et al. (2004)	DERMIS	✓	Emergency response system	Decision support	Delphi method	1	0
46	Turoff et al. (2006)	CRISIS game		Computer mediated communication system	Emergency preparedness	Field test	1	0
47	Wickler et al. (2006)	OpenCVE.net	✓	Virtual collaboration environment	Collaboration	Experiment based	1	0
48	Wickler et al. (2011)	VCE		Virtual collaboration environment	Community response	Experiment based	1	0
49	Xue & Liang (2004)	PHEIS	✓	Public health emergency information system (PHEIS) in China	Emergency response	Case study	0	1
50	Yang et al. (2009)	SafetyNET	✓	Short and long range wireless communication using sensor network	Emergency response	Experiment based	1	0
51	Yao, et al. (2005)	Webboard		Virtual group decision	Emergency preparedness	Case study	1	0

Note: 1 = Yes, 0 = No.

Past Action Research studies on EMIS.

Author(s) (year)	Problem/issue	Theory	Client	Data collection method	Change agent (IS)	Findings	Lessons for this research
Howe et al. (2011) Disaster focused: Earthquake & Tsunami	First responders who are people from local are not trained professionals for disaster response. Leveraging citizens to self-organize a crisis response is crucial.	Rayport and Heyword (2009) model Situational Awareness models	10,000 people for US and 49,000 people for Europe exercises	Surveys After action reports Author's participation and observation as one of leaders from Exercise 24	Social media, cloud computing & crowd sourcing tools: Wiki, Facebook, Twitter, and Global Talk	Self-organizing groups can form and respond to a crisis using low-cost social media and other emerging web. Social media is a valuable and powerful information tool in the future of emergency management technologies.	Incorporate social media tools to actively engage emergency managers and all stakeholders in EM. Register the participants in the discussion to reduce unverifiable information.
Raman et al. (2010)Disaster focused: All AR Form: CAR	Most organizations face difficult challenges in managing knowledge for emergency Response.	Information Theory	Emergency Operations Center (EOC) of Claremont University Consortium	Interview focus group Direct observation as Emergency Preparedness Assistant	Groupware solution: Wiki-based Knowledge Management System (KMS)	Successful implementation of an emergency management system is contingent on the ability of the system to blend with the nature of tasks involved in emergency response.	IS solution proposed that EM should assume the notion of fit between knowledge tasks and KM technology. This could be ensured by analyzing the tasks involved and how the proposed KMS can handle the knowledge processes
Toomey et al.(2009) Disaster focused: Wild land fire	Emergency managers are not fully aware of the assistance of GIS for effective emergency management	Davis' Technology Acceptance Model (TAM)	The County of San Diego's Office of Emergency Services	Direct observation as GIS Analyst Review of reports	Integrated Geospatial tools: Geographical Information System (GIS), Cartography, Geovisualization	The maps from the tools provided situational awareness and offered a medium to convey vital information such as fire parameter, evacuation data, assess health issues, potential impacts of services and more	The IS tools provide SA to emergency managers to enable the most efficient response. This study instructs researchers that any IS introduced to the social setting must ensure that emergency managers positively perceive usefulness and ease of use of the solution. These are incorporated in design decisions of the KMS design in this research.

Appendix B. (*continued*)

Author(s) (year)	Problem/issue	Theory	Client	Data collection method	Change agent (IS)	Findings	Lessons for this research
Fruhling et al. (2006) Focus: Public health emergency	Lack of efficient electronic sharing of critical health microbiology laboratory information in emergency situation especially in rural areas.	Turoff et al. (2004) set of 8 general and supporting design principles	Nebraska Public Health Laboratory	Qualitative – direct observation, user feedback, GSS workshops, system documentation Quantitative – usability evaluation	Group Support Systems: Laboratory diagnostics & Consultation system	GSS used under the right conditions can translate the potential benefits into real organizational value.	Adaptiveness and flexibility are two key designs considered for this research. Facilitated workshops are beneficial to improve participation. Usability evaluation and feedback sessions are important for system evaluation stage.

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