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ROLE OF GIS, RFID AND HANDHELD COMPUTERS IN EMERGENCY MANAGEMENT: AN EXPLORATORY CASE STUDY ANALYSIS

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ABSTRACT

This paper underlines the task characteristics of the emergency management life cycle. Moreover, the characteristics of three ubiquitous technologies including RFID, handheld computers and GIS are discussed and further used as a criterion to evaluate their potential for emergency management tasks. Built on a rather loose interpretation of Task-technology Fit model, a conceptual model presented in this paper advocates that a technology that offers better features for task characteristics is more likely to be adopted in emergency management. Empirical findings presented in this paper reveal the significance of task characteristics and their role in evaluating the suitability of three ubiquitous technologies before their actual adoption in emergency management.

Keywords: Emergency management; RFID; Task-technology Fit Model; Ubiquitous Technologies

1. INTRODUCTION

Mark Weiser (1991, p. 94) introduced the concept of ubiquitous technologies in 1991 by stating as:

> *"The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it".*

Since then, the world has witnessed rapid growth and eminent success in the adoption and diffusion of ubiquitous technologies in various disciplines including education, science, defence and public service (Chainey and Ratcliffe, 2005; Loebbecke and Palmer, 2006; Sara, 2003; Shannon, and Feied, and Smith, and Handler, and Gillam, 2006). Moreover, it is important to note that the use of emerging technologies that have unique characteristics is still not well understood (Sharma, and Citurs, and Konsynski, 2007). Therefore, to evaluate the performance of technologies before their actual adoption is still believed to be quite intricate (Davies and Gellersen, 2002).

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This paper is built on the key concept of Task-technology Fit (TTF) model presented by Goodhue and Thomson. In their paper presented in MISQ in 1995, Goodhue and Thompson (1995, p. 216) described Task-Technology Fit as:

> "[The] *degree to which a technology assists* [its users] *in performing his or her portfolio of tasks. More specifically, TTF is the correspondence between task requirements,* [users'] *abilities, and functionality of a technology".*

It is further argued that the better 'fit' between task and technology characteristics increases the likelihood of adoption of a technology in a particular domain (Goodhue and Thompson, 1995, p.216). Aligned with the above argument, this paper suggests that a better 'fit' between task characteristics of emergency management and technology characteristics of ubiquitous technologies increase the likelihood of successful adoption of these technologies in this domain. However, before examining the 'fit', it is commendable to address the task and technology characteristics. Therefore, the objectives of this paper are as follows:

a. Identify task characteristics of emergency management, and

b. Identify technology characteristics of RFID, handheld computers and GIS.

Overall, this paper is structured as follows: firstly, the paper addresses the task characteristics of emergency management and technology characteristics of RFID, Handheld computers and GIS. Next, the paper presents a conceptual model and then outlines the research methodology. Later on, the paper presents the research findings. The paper includes the justification of unplanned results generated from multiple case studies, and it ends with a discussion and conclusion.

2. TASK CHARACTERISTICS OF EMERGENCY MANAGEMENT

Emergency management life cycle is generally described as a series of various phases or stages such as preparedness, mitigation, response and recovery (Kimberly, 2003). Literature relevant to emergency management reported several models that describe various numbers of phases such as three phases (ADPC., 2000; Atmanand, 2003; Tuscaloosa., 2003), four (Kimberly, 2003; Turner, 1976), six (Toft and Reynolds, 1994), seven (Shaluf, Ahmadun, and Mustafa, 2003) or even eight (Kelly, 1999) phases which collectively form the emergency management life cycle. In depth analysis of these emergency management models reveals that they comprise of various individual tasks. For instance, a task such as 'information sharing' is performed in different phases of emergency management including preparedness, mitigation, response and recovery. Similarly, an individual phase may include more than one task. For instance, response phase may include such tasks as 'information sharing' and 'resource management'. In general, this paper agrees with the description of emergency management in terms of phases or stages. However, this paper advocates that the concept of phases does not facilitate the process of technological adoption. Furthermore, aligned with the recommendation of Goodhue and Thompson (1995, p. 216), this paper argues that the objective of adoption of a technological process is to facilitate a particular task and not a phase.

In order to identify the task characteristics of emergency management, this paper built on two streams of literature, including:

1- Emergency management models – theoretical models suggesting various phases of the emergency management life cycle. The following section reports various tasks mentioned in these emergency management models.
2- Emergency management studies – case studies discussing several tasks performed in real emergencies situations. Section below lists various tasks reported in various emergency management case studies.

2.1 Emergency Management Models

The following tasks are mentioned in various emergency management models:

- People/victim management (ADPC. (2000); Kelly, 1999; B. Richardson, 1994)
- Planning (Manitoba-Health-Disaster-Management., 2002; B. Richardson, 1994; I.M. Shaluf, and F.R. Ahmadun, and S. Mustapha, 2003)
- Information sharing (Manitoba-Health-Disaster-Management., 2002; B. Richardson, 1994)
- Immediate response to disaster (B. Richardson, 1994)
- Training (ADPC., 2000; Kimberly, 2003; Tuscaloosa., 2003)
- Communication (ADPC., 2000; Kimberly, 2003; Manitoba-Health-Disaster-Management., 2002)
- People and object management (ADPC., 2000; Kelly, 1999; Kimberly, 2003)
- Maintenance of inventories (ADPC., 2000; Atmanand, 2003)
- Conducting drills (ADPC., 2000; Atmanand, 2003; Tuscaloosa., 2003)
- Resource management (ADPC., 2000; Atmanand, 2003; Kelly, 1999; Tuscaloosa., 2003)
- Authentication (Toft and S. Reynolds, 1994; Turner, 1976)
- Detecting emergency signals (B. Richardson, 1994; I.M. Shaluf et al., 2003)
- Tagging/tracking (Kelly, 1999)

2.2 Emergency Management Studies

The following tasks are mentioned in various emergency management case studies:

- Resource management (Haddow, and Bullock, and Coppola, 2008; José, and Pérez, and Ukkusuri, and Wachtendorf, and Brown, 2007; E.L. Quarantelli, 1997; Tran, and Yousaf , and Wietfeld, 2010)
- Information management (Celik and Corbacioglu, 2010; José et al., 2007; E.L. Quarantelli, 1997; Tomasinia and Wassenhoveb, 2009; Tran et al., 2010; S. Zlatanova, and P. Oosterom, and E. Verbree, 2004a)
- Training (José et al., 2007; Wilks and Page, 2003)
- Automation (Carver and Turoff, 2007; Zlatanova et al., 2004a)
- Coordination and collaboration (Carver and Turoff, 2007; Celik and Corbacioglu, 2010)
- Authentication (Haddow et al., 2008; Tran et al., 2010)
- Tagging and Tracking (Carver and Turoff, 2007; Tomasinia and Wassenhoveb, 2009; Zlatanova et al., 2004a)

The above discussion presents a number of tasks that are performed in the emergency management life cycle. However the careful analysis of such tasks suggests that some tasks such as ‘communication’, ‘resource management’ and ‘information management’ are reported more than once across various phases of the emergency management life cycle. Similarly there are few tasks that are identical in nature such as ‘resource management’, ‘people and object management’. It is also important to note that a number of tasks mentioned above are not relevant to the context of this research that is about the role of ubiquitous technologies in emergency management. In order to clearly understand the eminent tasks involved in the emergency management life cycle, it is wise to group similar tasks and form the key groups of tasks which can be used as ‘task characteristics’ of emergency management.

The relevant literature suggests that tasks have been categorized across three dimensions: (a) difficulty, (b) variety and (c) interdependence (W. Louis Fry and Slocum, 1984). However, the research related to technological adoption asks whether a significant difference exists between variety and difficulty (L. Dale Goodhue, 1995; Wells, and Sarker, and Urbaczewski, and Sarker, 2003). Nevertheless, the overall process of task analysis involves a hierarchical decomposition of autonomous tasks into lower-level sub-tasks (Hackos and Redish, 1998). The nature of an autonomous task dictates the degree of variety, difficulty and interdependence of a particular task (Wells et al., 2003). In contrast to decomposing tasks into sub-tasks based on the variety, difficulty and interdependence, sub-tasks can be grouped together to form major tasks based on their common attributes. Aligned with the above line of argument, this research agrees that emergency management tasks can be grouped into major tasks based on their common attributes. In addition, this research also carefully considers the recommendations of Wells et al. (2003) who argues that the overall classification of tasks is primarily based on the domain characteristics and context of that classification. Therefore, in context of technological adoption, this paper combines the emergency management tasks based on their commonalities and form the key task characteristics of emergency management.

Task – A: Authentication

In order to protect a system from an emergency or disaster - especially a man-made disaster - it is critical to protect that system from an unauthorized or illicit use. Toft and Reynolds (1994), Haddow et al (2008) and José et al.(2007) suggest that the following tasks should be performed for the safe, secure and authorized use of a system.

- Implementing authentication protocol
- Assigning privileges to the users
- Verification of access requests

Aligned with the above recommendations, this paper argues that the above mentioned tasks are critical for system security, and thus a technology that offers better support for these tasks is more likely to be adopted in emergency management. Moreover, this paper places the above mentioned tasks under a broader category of related tasks and calls it as ‘authentication’. This task (authentication) assures that only valid users can interact with the system, which will eventually minimize the risks of various man-made disasters such as technological disasters and terrorist attacks. Use of technology for authentication refers to the process through which a pertinent technology is used to verify the identity of a user who wishes to access a system.

Task – b: Automation

Literature related to emergency management suggests that during emergencies, data is available from many sources and in huge quantities, but the actual problem arises in the processing of this data (Zlatanova et al., 2004a). During emergencies, unfavourable working conditions further complicate the required working performance from human operators. During hostile working environment of emergencies, a technology that can automate various procedures and ensure consistency is likely to be adopted successfully (M. Ibrahim Shaluf, and R. Fakharul Ahmadun, and Sa'Ari. Mustapha, 2003; S. Zlatanova, and P. Van. Oosterom, and E. Verbree, 2004b). Furthermore, the relevant literature has identified the following tasks which could be better performed with the help of a suitable technology (Carver and Turoff, 2007; B. Richardson, 1994; I.M. Shaluf et al., 2003; Zlatanova et al., 2004a). These tasks are:

- Identification of tasks which can be performed by control systems
- Automatic detection of inputs using sensors
- Automatic decision making based on received data- using artificial intelligence

Built on common attributes of the above mentioned tasks, this paper groups them into a broader category and calls it as 'automation'. In general, automation also refers to a process of using a control system, such as computers, to control machinery and processes and replacing human operators (2002).

Task – C: Tagging and Tracking

One of the most important and urgent problems at the emergency scene is the overwhelming number of victims that must be monitored, tracked and managed by each of the first responders or individuals (Barbara, 2008; Killeen, and Chan, and Buono, and Griswold, and Lenert, 2006; Bill Richardson, 1994; Tuscaloosa., 2003). In addition, the equipment deployed at the emergency scene needs to be managed appropriately. It is suggested that the whole process of managing humans and other objects during emergencies is composed of following tasks (ADPC., 2000; Kelly, 1999; Kimberly, 2003; B. Richardson, 1994):

- Marking or tagging of humans and objects
- Use these tags to track humans/objects
- Use these tags for objects management before, during, and after emergencies.

Aligned with the existing literature, this paper agrees that a technology that offers better features to conduct these tasks would be well accepted in emergency management. Based on the common attributes of the above tasks, this paper groups them into a broader category of 'tagging and tracking'. By definition, the purpose of tagging and tracking is to identify the target object in a group of similar objects, as well as to keep real-time information about its position. In the context of emergency management, people and object management are the main objectives of this task (Schulz, and Burgard, and Fox, and Cremers, 2001) and this paper identifies it as one of the key task characteristics of emergency management.

Task – d: Information Management

Wybo and Kowalski (1998) argue that the lack of inadequate and incomplete information is considered to be the main operational problem during emergency management. A study of recent emergencies shows that, at one or another level, information was available that could have prevented the emergency from happening (Chan, and Killeen, and Griswold, and Lenert, 2004; Kelly, 1999; Lee and Bui, 2000;

Mansouriana, and Rajabifardb, and Zoeja, and Williamson, 2006; Enrico L. Quarantelli, 1988; M. Ibrahim Shaluf et al., 2003; B. Toft and S. Reynolds, 1994). Further to the importance of 'information' in emergency management, the following are some of the tasks that are reported in the literature (Celik and Corbacioglu, 2010; José et al., 2007; Manitoba-Health-Disaster-Management., 2002; B. Richardson, 1994; Tran et al., 2010):

- Collection of information from various sources
- Broadcast warnings/alerts
- Building and maintaining information pools
- Communication with other agencies

Based on the common attributes in the above tasks, this paper segregates the above mentioned tasks into a broader category of 'information management'. This task refers to the collection and management of information from one or more sources, and its distribution to one or more audiences who have a stake in that information or a right to that information. In context of technological adoption, this paper advocates that, information management and communication play a vital role (Enrico and Quarantelli (1988)) and act as an important task characteristics of emergency management.

Four tasks characteristics including authentication, automation, tagging / tracking and information management are collectively referred as AATI in this paper.

3. UBIQUITOUS TECHNOLOGIES

According to Kumar and Chatterjee (Kumar and Chatterjee, 2005) ubiquitous technology is the trend towards increasingly ubiquitous, connected computing devices in the environment, a trend being brought about by a convergence of advanced electronic - and particularly, wireless-technologies and the Internet. Ubiquitous technology is pervasive in nature and unobtrusively embedded in the environment, completely connected, intuitive, effortlessly portable, and constantly available. Although there are several ubiquitous technologies available such as RFID, handheld computers, GIS, GPRS, wearable computers, smart homes and smart building, this paper focuses only on three technologies including RFID, handheld computers and GIS.

3.1 Radio Frequency Identification

RFID is a term coined for the use of short to medium range radio technology for the communication between two objects without any physical contact (Wang, and Chen, and Ong, and Liu, and Chuang, 2006). Objects on the two sides of the RFID link can be either stationary or moveable. A typical RFID system consists of (a) tag, (b) reader/interrogator, and (c) an antenna. When the reader sends out the electromagnetic signals to couple with the tag antenna, the tag gets electromagnetic energy from waves to power its circuits in the microchip. The microchip located inside the tag then sends back electromagnetic waves to the reader, and the reader receives and returns the waves and converts them into digital data. The data transmitted by the tag actually provides the data and information for the object, and the information can be processed in any information system or network connected to the reader (Xinping, and Yuk, and Sheung, 2007). Contactless and no line of sight communication are the key features of RFID.

Literary volumes of research are available on the application of RFID in various domains. Most significantly, this technology has been used in supply chain management, inventory control, asset management, retail, manufacturing, warehouse automation, security, defence, aerospace, road pricing, fashion, libraries, hospitals, telemedicine and farm management.

Further to the use of RFID in the above mentioned domains, Fry and Lenert (2005) proposed the use of RFID in hospitals during a disaster, such as a mass causality situation. An integrated RFID-equipped hardware-software system (MASCAL) was designed to enhance a hospital's resource management capabilities. The RFID-equipped system (MASCAL) was targeted at conducting the tasks related to patient management during an emergency with improved efficiency and better performance. The MASCAL system created an end-to-end environment for the management of casualties from a battlefield or catastrophic civilian event. The system utilizes positional information from wireless asset tags to reduce dependencies on manual processes, and it improves situational awareness during inherently chaotic events. Its potential value lies in providing visibility into the supply and demand workflows, augmented with select data that is considered helpful in making appropriate management decisions.

3.2 Handheld Computers

Handheld computer also referred to as personal digital assistants (PDAs). These are lightweight, compact computers that are literally held in one's hand or stored in a pocket (Lu, and Xiao, and Sears, and Jacko, 2005). These gadgets have developed increasing functionality, with decreasing size and weight. In addition to mobility and ubiquity, they offer high resolution colour displays and provide sufficient memory to store a large amount of data (Kho, and Henderson, and Dressler, and Kripalani, 2006). Latest handheld computers have larger screens, the ability to run multiple programs simultaneously, and natural handwriting recognition software. These devices allow users to access electronic mail and the internet remotely, creating virtually limitless access to the information.

During emergencies, the use of the Internet on these devices can provide useful information about emergencies and disasters to the public and first responders (Alfonso and Suzanne, 2008). Furthermore, such devices have the ability to enable responders to work well with others due to their ability to communicate quickly and share resources (Pine, 2007).Wireless technology ranges from doing simple tasks, such as communicating with first responders remotely, to more complex tasks such as collecting digital data efficiently and accurately (Troy, and Carson, and Vanderbeek, and Hutton, 2008).

3.3 Geographic Information System

GIS integrates hardware, software, and data for capturing, managing, analysing, and displaying all forms of geographically referenced information. It is a powerful tool for various organizations because it has the ability to capture the data by digitizing, scanning, digital imagery, or aerial photography. Databases associated with GIS applications can be used (a) to store the data, (b) to manipulate the data, (c) to form data queries and (d) to visualize the data (Gunes and Kovel, 2000).

GIS technology can play an important role in emergency management because it has the ability to enhance emergency management information systems by digitally capturing, storing, analysing and manipulating data (Senior and Copley, 2008). Because of its ability to gather, manipulate, query and display geographic information quickly and present it in an understandable format, GIS could be decisive for emergency management (Cutter, and Emrich, and Adams, and Huyck, and Eguchi, 2007). Table 1 summarizes some of the key characteristics of RFID, handheld computers and GIS.

Table 1: Characteristics of Ubiquitous Technologies

RFID	Handheld computers	GIS
Tracking, scanning, information management, automation (Michael and McCathie, 2005)	Data storage, transformation and transmission (Lu et al., 2005)	Digitally captures, stores, analyses and manipulates data (Senior and Copley, 2008)
Automatic non-line of sight scanning, labour reduction, enhanced visibility, item level tracking, robustness (2005)	Real-time data gathering, concurrent data transformation and instant data transmission (Kho et al., 2006)	Ability to gather, manipulate, query and display geographic information (Cutter et al., 2007).
Automation, object tracking, asset management, object management. (Xiao, and Shen, and Sun, and Cai, 2006)	Communication and information management (Pine, 2007)	Analytical modelling (2000)

4. CONCEPTUAL MODEL

The rationale for building a conceptual model on the theory of TTF is an argument that claims that '*there must be a good fit between the technology and the tasks it supports'* (Goodhue and Thompson, 1995). It also claims that 'good fit' between task and technology features brings performance improvements to its users. Built on the notion of '*task-technology fit'*, a conceptual model is presented that highlights the task characteristics of emergency management and technology characteristics of radio frequency identification, handheld computers and geographic information system and the 'fit' between task and technology characteristics.

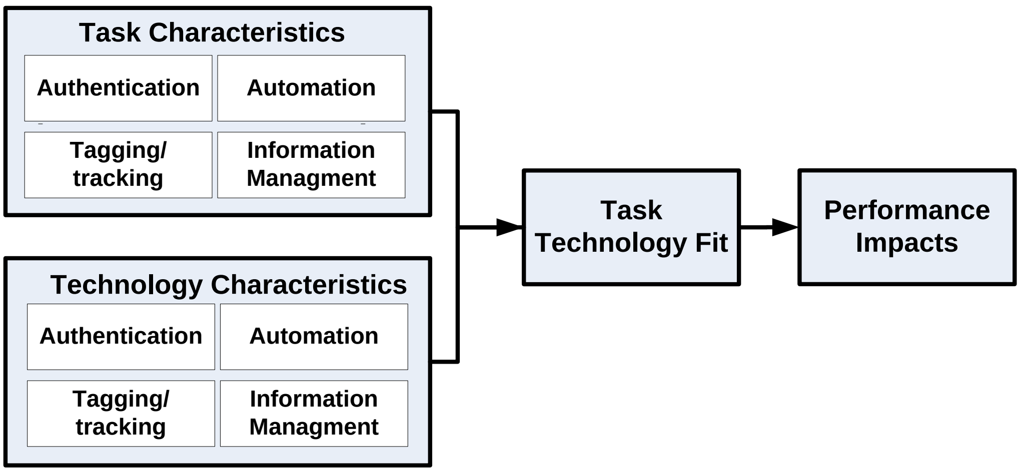

Figure 1: Conceptual Model based on TTF

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Task Characteristics refer to the key tasks performed in the emergency management life cycle, such as authentication, automation, tagging/tracking, and information management (AATI). These tasks are derived from the relevant literature and then contextualized for this study. As discussed above, AATI are the key emergency management tasks which need to be performed by the use of any pertinent technology.

Technology Characteristics refer to the features of ubiquitous technologies that perform the task requirements of authentication, automation, tagging / tracking and information management. Once the task characteristics of emergency management are identified (as AATI in this study), the potential technology needs to be evaluated against such tasks.

Task-technology Fit refers to the degree by which task characteristics match with the technology characteristics. It also addresses the factors that influence the 'fit' between task and the characteristics of ubiquitous technologies.

Performance Impacts refer to the perceived impacts of technological adoption on the performance of emergency management operations.

This paper only examines the task and technology characteristics whereas discussion on TTF (factors) and performance impacts (mentioned in the conceptual model) is not under the scope of this paper.

5. RESEARCH METHODOLY

By employing a conceptual study, four major tasks of emergency management are identified (as reported in the Section above). Moreover, multiple case study method is adopted to empirically validate the significance of those tasks. Five emergency management organizations are selected to participate in this research. Out of the total five cases, three are located in Australia, one in New Zealand and one in Switzerland. Although, five cases are too few to allow statistical validity, they do allow a large enough range to result in an acceptable theoretical replication. Moreover, many well-known case studies have used this number or fewer cases (Dick, 2002; Eisenhardt, 1989; Markus, 1983; Orlikowski, 1983). The cases selected for this research cover the variations in the evaluation process within the context of technological adoption in emergency management. The criteria for selecting the participating organizations were based on the fact that those organizations have already used or are willing to use any ubiquitous technology in emergency management. The selection criteria are imposed to achieve analytical generalization whereas statistical generalization is not targeted in this study. In relation to the triangulation of data, data was collected from multiple sources, including formal interviews, organizations' websites, email communication, telephone conversations, and other relevant documents (see Table 2 for more details). However, the case studies mainly rely on the formal in-depth interviews with the eight key participants from the selected cases (each case represented by a unique alphabet such as A, B, C, D and E). Primary data was collected from eight respondents including Director disaster operations (DDO), Executive Manager Disaster Operations (EMDO), Coordinator Emergency Management (CEM), Team Lead Spatial Systems (TLSS), Regional Director Emergency Management (RDEM), Director Emergency Management and Communication (DEMC), Senior Logistics Officer (SLO) and Logistic Officer (LO) representing five case organizations. Data collected from the other sources assists in further understanding and explaining the data from the formal interviews, providing a contextual richness to the collected data. With the consent of the participants of the case studies, all conversation held during an interview was recorded on a digital voice recorder. The recorded interviews were further transcribed in total and analysed by a pattern matching technique. The qualitative analysis tool called NViVo 8.0 was used for such a purpose.

Table 2: Overview of Supporting Documents

Case	Document Name	Abbre-viation	Accessi-bility	Overview
A	Critical Infrastructure Emergency Management Assurance Handbook	CIEMAH	Public	This handbook provides information for senior emergency risk managers dealing with critical infrastructure. The handbook complements and supports AS/NZS 4360: 1999 Risk Management and Emergency Management Australia's Emergency Risk Management Application Guide.
	Disaster Management Planning Guidelines	DMPG	Public	The aim of these guidelines is to provide a process for local governments to develop a local disaster management plan, and to understand the need for a consistent local government approach to disaster management planning.
	Emergency Risk Management	ERM	Public	The aim of emergency risk management (ERM) is to present a systematic process that produces a range of risk treatments that reduces the likelihood or consequences of disastrous events.
	Disaster Management Plan	DMP	Public	Disaster management plan outlines the potential hazards and risks that are evident in an area; steps to mitigate these potential risks; and an implementation strategy to enact should a hazard impact and cause a disaster.
	The Overview of Disaster Management Arrangements	DMA	Public	It is intended for this book to provide a high-level overview for anyone interested in disaster management arrangements in the State, including disaster managers, stakeholders and communities.
B	*None*			

C	Emergency Management Planning Guide	EMPG	Public	The aim of the emergency management planning guide is to assist local councils and communities to better assess and manage emergencies such as flood, storms and earthquakes, in order to reduce the consequences of disastrous events and to create safe and resilient communities.
	Response Plan for Victoria	RPV	Public	The purpose of this plan is to provide strategic guidance for effective emergency response to flood events. The plan also describes the roles and responsibilities of agencies and organizations that have a role in the floodplain management, forecasting of meteorological events, dissemination of information to the community and the role of minimizing the threat and impact to people, property and the environment.
	Emergency Management Discussion Paper	EMDP	Public	The emergency management discussion paper provides a range of suggested recommendations on how to address the challenges arising from changing demographics, community expectations and regulatory environments for emergency management.
D	Disaster Response and Contingency Planning Guide	DRCPG	Public	Disaster response and contingency planning is a management tool that helps to ensure organizational readiness and that adequate arrangements are made in anticipation of an emergency. Thoughtful execution of planning can help to ensure that the resource needs for any type or size of disaster, no matter where or when it strikes, are met quickly and effectively.
	Disaster Management Operational Strategy	DMOS	Public	The objective of the disaster management operational strategy is to strengthen disaster management tools and systems, analysis, planning, funding tools and cross-divisional integration practices to ensure most effective stewardship of donations so the organization can provide more disaster management services to more vulnerable people.
E	*None*			

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6. EMPIRICAL EVIDENCES

In context of tasks involved in emergency management, the following discussion covers the empirical evidence collected from the participating case organizations. In response to an open-ended question about the task characteristics of emergency management, the interviewees from the participating case organizations identified several tasks in their discussions. Such tasks are identified by using NViVo 8.0 and are given below:

- **DDO–Case A** suggests (i) Train, teach and practice with individuals (ii) Facilitate communication and information flow (iii) Collect, collate, analyse and distribute information (iv) Maintain distribution lists and systems (v) Maintain information accuracy.
- **EMDO–Case A** suggests (i) Keep track of volunteers and equipment going out in emergencies (ii) Automated and quick distribution of information to the target audience (iii) Information dissemination; (iv) Training (v) Coordinate a state-level response to all hazards and recovery from any disaster (vi) Maintain and enhance equipment.
- **CEM–Case B** suggests (i) Drills; (ii) Asset management system (iii) Authentication (iv) Communication and sharing of information with other emergency management organizations (v) Resourcing and resource allocation.
- **TLSS–Case B** suggests (i) Keep records of things deploying to emergencies (ii) Keep up to date information about emergencies (iii) Incident management system (iv) Information sharing and dissemination.
- **RDEM–Case C** suggests (i) Respond to floods, earthquakes, tsunamis and rescues the victims (ii) Training (iii) Communication (iv) Access the system according to privileges granted.
- **DEMC–Case C** suggests (i) Managing incoming emergency related calls (ii) Issue emergency warnings (iii) Situational awareness (iv)Information dissemination (v) Resource management.
- **SLO–Case D** suggests (i) Development of global infrastructure and response capacities (ii) Field support (assessment and set-up of operations) (iii) Disaster response (iv) Disaster preparedness (v) Tagging and tracking of goods (vi) Management of emergency related information.
- **LD–Case E** suggests (i) Planning for emergency management (ii) Communication (iii) Authentication (iv) Use of an automated system that can replace humans or at least assists them during the emergencies (v) Track the goods through the system (vi) Inventory management.

In addition to the tasks identified by key informants, the participants of the case study were also invited to record their feedback on the significance of four tasks (such as AATI) suggested in this paper. Following discussion reports the feedback recorded from case study interviews along with the empirical findings on the significance of authentication, automation, tagging/tracking and information management.

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6.1 Authentication: Empirical Findings

Empirical evidence related to authentication reveals that the interviewees from four out of five of the case study organizations supported this task as one of the key tasks in the emergency management life cycle. Only one case (that is, Case D) rated the significance of this task as ‘moderate’ in the emergency management life cycle. By analysing all the important facts related to this task, it was found that authentication is more critical during pre – (before) disaster or the planning phase than during or post – (after) the emergency. Table 3 depicts the significance of authentication in various stages of the emergency management life cycle.

Table 3: Significance of Authentication

Case	Key Informant	Before	During	After
A	DDO	X	-	-
	EMDO	X	X	X
B	CEM	X	X	X
	TLSS	X	X	X
C	RDEM	X	-	-
	DEMC	-	-	X
D	SLO	-	-	-
E	LD	X	-	-

Although, the findings given in Table 3 reflect the importance of authentication in various stages of emergency management, this research further processed the qualitative data gathered at the end of data collection phase and convert into quantitative results. This paper also supports the argument of Katharina and Sabine (2007), which states that the qualitative data can be converted into quantitative results for better understanding and for rigor empirical findings. Furthermore, Bazeley (2002) and Christina et al. (2002) also claimed that the mixed-method research has gained acceptability and becomes increasingly popular in empirical research.

Based on the above arguments, this paper calculated the relevance of the proposed tasks in emergency management. In order to do so, weighted average of such tasks is calculated based on the following formula (called, R1).

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$$R1 = \text{Relevance} = \frac{\sum_{i=1}^{3} a x_i}{j \times k}$$

Where:

a_1 = Supported = 2

a_2 = Neutral = 1

a_3 = Not supported = 0

x_i = Number of case study participants for a particular response

j = Total number of case study participants

k = Maximum possible score for any response = 2

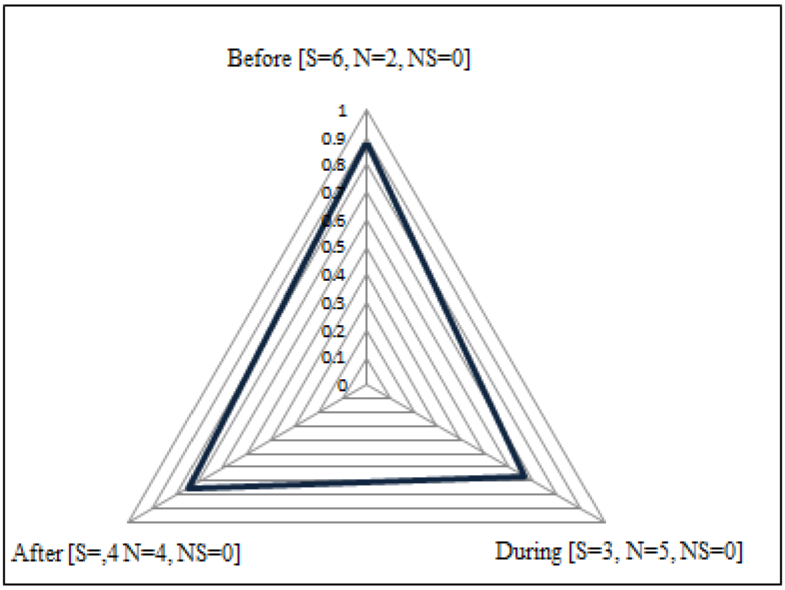

Figure 2: Relevance of Authentication

As depicted in Figure 2, authentication remains critical throughout the emergency management life cycle. In short, ensuring a rigorous authentication system could certainly minimize the likelihood of a potential emergency situation, such as terrorist attack.

In Figure 2 to 6, "S" represents the number of participants who supported an argument, "N" represents Neutral and "NS" represents Not Supported.

6.2 Automation: Empirical Findings

A key argument in support of this task is the fact that during emergencies, human performance does not remain consistent. Extreme climatic conditions and an unfavourable working environment are considered as major factors in creating this inconsistency. Therefore, control systems are highly desirable in emergency management, as they can perform consistently even in unfavourable working conditions. The empirical evidence shows that automation is more important during an emergency than it is before or after an emergency situation. Table 4 highlights the importance of automation at various stages of the emergency management.

Table 4: Significance of Automation

Case	Key Informant	Before	During	After
A	DDO	-	X	-
	EMDO	-	X	-
B	CEM	-	X	-
	TLSS	X	X	X
C	RDEM	X	X	X
	DEMC	X	X	X
D	SLO	-	X	-
E	LD	-	X	-

It is important to note that all participants of this case study supported this task especially during emergencies. Key argument in favour of this task is the fact that humans are unable to work consistently and efficiently during unfavourable working conditions of emergencies. Thus, a technology that could assist humans during emergencies is very well supported.

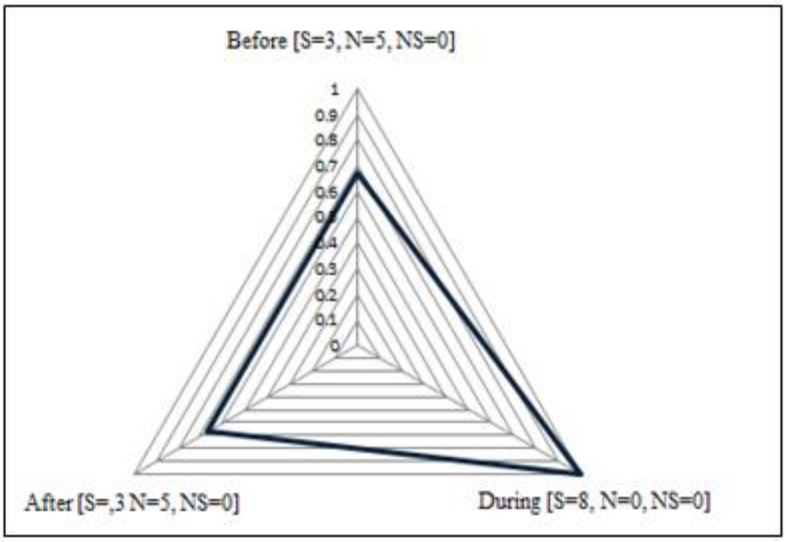

Figure 3: Relevance of Automation

6.3 Tagging/Tracking: Empirical Findings

It is interesting to note that, through the data collected from the key informants, this task remains critical throughout the emergency management life cycle. Table 5 and Figure 4 summarize the significance of this task and its relevance during various stages of emergency management.

Table 5: Significance of Tagging/Tracking

Case	Key Informant	Before	During	After
A	DDO	X	X	X
	EMDO	X	X	X
B	CEM	X	X	X
	TLSS	X	X	X
C	RDEM	-	X	X
	DEMC	X	X	X
D	SLO	X	X	-
E	LD	X	X	X

Figure 4 summarizes the number of case study participants that supported the significance of tagging/tracking and the overall relevance of this task is also presented in Figure 4 below:

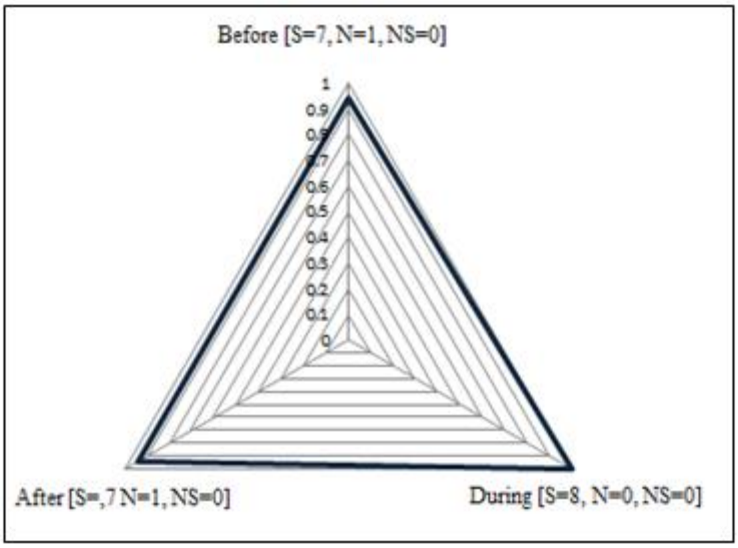

Figure 4: Relevance of tagging/tracking

Overall, this task consists of two sub-tasks: first, tagging of humans or other objects, and second, use of tags or marks for tracking them. During the case study interviews, tagging/tracking is reported as a very important task in emergency management with a special emphasize during an emergency and it was related to the better management of humans and objects in the emergency management life cycle.

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6.4 Information Management: Empirical Findings

Information management is considered as the backbone of, and remains critical throughout the emergency management life cycle. It is a task that connects all the other tasks and operations together. Furthermore, the empirical evidence collected from the participating case organizations reveals that information management plays an important role throughout the emergency management life cycle. Table 6 highlights the significance of this task in various stages of the emergency management life cycle.

Table 6: Significance of Information Management

Case	Key Informant	Before	During	After
A	DDO	X	X	X
	EMDO	X	X	X
B	CEM	X	X	X
	TLSS	X	X	X
C	RDEM	X	X	X
	DEMC	X	X	X
D	SLO	X	X	-
E	LD	X	X	X

In addition to the key informants, Figure 5 depicts the number of case study participants that supported information management as a key activity, along with its relevance in various stages of the emergency management life cycle.

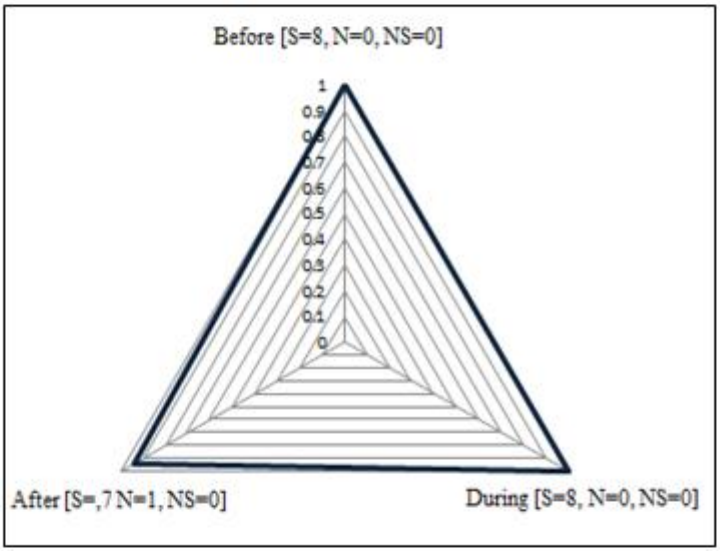

Figure 5: Relevance of Information Management

Data shown in figure 5 corroborates the initial claim made by this research. It is evident that information management is one of the most important tasks in emergency management and use of technology that can assist in conducting this task are more likely to be welcomed by the emergency management organizations.

7. RELEVANCE OF AATI

The above sections reported the empirical evidence collected from the participating case organizations and are further analysed and used to portray the significance of AATI before, during and after an emergency situation. Based on the number of participants who supported AATI, the overall relevance of each of the four tasks is calculated across the entire emergency management life cycle and is shown in Figure 6 below:

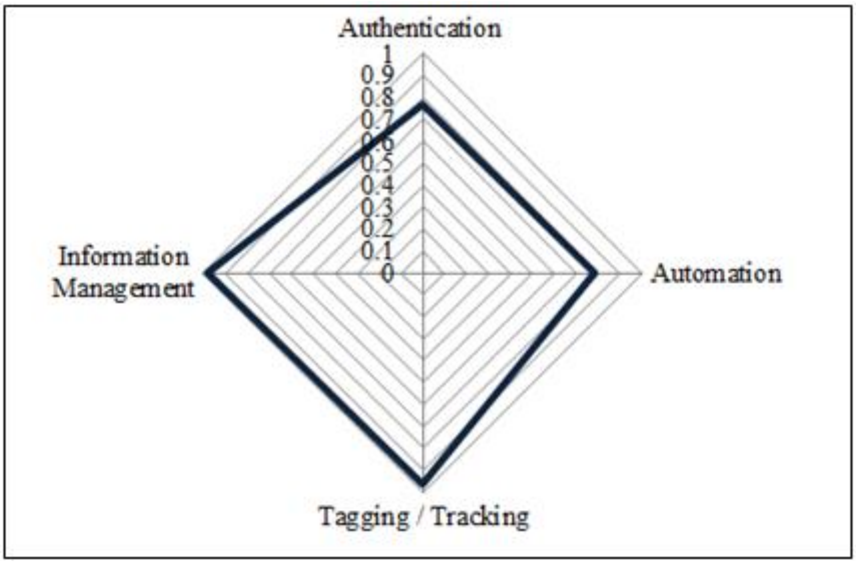

Figure 6: Relevance of AATI

The empirical findings reported in Figure 6 reveals that in the context of technological adoption, information management is the most important task requirement. After this, tagging/tracking is considered as the next most important task; automation is considered as of moderate importance and authentication as the least important task in emergency management.

8. JUSTIFICATION OF OTHER TASKS

In addition to the support of AATI as key characteristics of emergency management, representative from first three cases (that is, case A, B and C) suggested that 'training' is another important task of the emergency management process (see Table 7 below). In order to understand the importance of training in emergency management, it is worthy to understand what 'training' actually means.

According to the definition at:

http://www.businessdictionary.com/definition/training.html, training can be described as:

> *"Organized activity aimed at imparting information and/or instructions to improve the recipient's performance or to help him/her attain a required level of knowledge or skill".*

In addition to the definition of training, Perry and Lindell (2003) described the role of training in the emergency management process. According to them, education and drills are key components of pre-emergency phase. Education in emergency management covers the preparation of emergency plans and involves communication amongst several emergency management personnel and organizations. On the other hand, drills can be viewed as the settings where problems are expected and conflicts can be resolved. These are the exercises that are performed in settings similar to actual emergency situations. Thus, the training process represents two aspects: (a) the transfer of information; and (b) drills/exercises/ simulations. During the interviews, it was perceived that the word 'training' was used to refer to both aspects (transfer of information and drills). During the interviews, it was perceived that the word 'training' was used to refer to both aspects ('transfer of information' and 'drills').

The following is a discussion of the two aspects of training and their associations with AATI in the perspective of technological use in emergency management.

Training as Transfer of Information: Training can be conducted in order to transfer information (knowledge). It also involves the management of information by the trainer as well as by the recipient. This aspect of training is generally used for emergency planning (Perry and Lindell, 2003). It ensures that the required information is available at the time of emergency. Furthermore, this aspect of training bridges the communication gap between several emergency management individuals and agencies that are working during emergencies. The role of technology in this aspect of training is to facilitate the process of the proper distribution and management of information. Thus, this aspect has already been covered under the broad category of information management and, then, this aspect of training did not satisfy the requirements to be considered an independent activity of emergency management.

Training as 'Drill' / 'Exercise' / 'Simulation': The other aspect of training covers the activities ('drills' / 'exercises' / 'simulations') that are performed in settings similar to a real emergency situation. This includes the simultaneous and comprehensive test of emergency plans, staffing levels, procedures, facilities, equipment and materials (Perry and Lindell, 2003).

According to Simpson (2002), there are a few differences between emergency management drill and the real emergency, such as:

- Drills/exercises are planned whereas most of the emergencies are unexpected;
- Drill/exercises are performed on a smaller scale as compared to real emergencies;

Unlike real emergencies, drills/exercises are performed under a controlled environment.

Other than the above-mentioned differences, comprehensive drills / exercises are the same as real emergencies; therefore, they go through all the phases and conduct all the activities (regardless of the scale) of the emergency management life cycle.

Based on the above discussion, it is evident that this aspect (drills / exercises) of training does not need to be declared an independent activity as all its requirements can be placed under the existing emergency management activities of authentication, automation, tagging/tracking and information management.

Although this research agrees that training is an important activity of emergency management, from the perspective of technological adoption in emergency management, all the underlying functions of the training process are covered under the broader categories of AATI.

9. DISCUSSION AND CONCLUSION

The early sections of this paper provided a comprehensive discussion on important emergency management studies. In addition to the discussion presented above, this paper agrees with the existing body of literature on the description of emergency management in terms of several phases or stages.

However, in the context of technological adoption, this research also highlights the following shortcomings in the existing literature (see Section 2 for more details):

- Existing emergency management models lack in uniformity in a number of the phases used to represent the emergency management life cycle.
- The concept of ‘phases’ or ‘stages’ of the emergency management process does not assist in evaluating the feasibility of technology for emergency management.
- Technology is used to perform a particular task, such as tracking of objects, information dissemination and authentication, not to perform a particular phase.

Thus, in order to overcome the above shortcomings, this paper identified the task characteristics of the emergency management process. Overall, these tasks are not only supported in the relevant literature (see Section 1) but their significance is also verified by the participants of multiple case studies (see Section 5). These tasks are further used as task characteristics in the conceptual model that has its roots in TTF (see Section 4). It is anticipated that the conceptual model presented in this paper could be used as a criterion to evaluate the potential of ubiquitous technologies before their actual deployment in emergency management. As a result of the above discussion, this paper concludes that: (i) from the perspective of technological adoption authentication, automation, tagging / tracking and information are the key tasks of the emergency management life cycle (ii) from the perspective of the adoption of ubiquitous technologies, information management and tagging / tracking are the most important tasks. Authentication is next in terms of importance and automation is the least important task (iii) the potential of a technology should be evaluated against its ability to perform the task characteristics (AATI) of emergency management and (iv) a technology that better supports the task characteristics could serve well in emergency management.

Table 7: Empirical Findings on the Significance of AATI

Case	**Task Characteristics of Emergency Management**												**AATI as Key tasks in Emergency Management**			**Other tasks in Emergency Management**
	Authentication			**Automation**			**Tagging /tracking**			**Information Management**						
	S	**N**	**NS**	**S**	**N**	**NS**	**S**	**N**	**NS**	**S**	**N**	**NS**	**S**	**N**	**NS**	
A	✓			✓			✓			✓			✓			Training
B	✓				✓		✓			✓			✓			Drills/ training
C	✓			✓			✓			✓			✓			Training
D		✓			✓		✓			✓			✓			None
E	✓			✓			✓			✓			✓			None

Legend: S: Supported, N: Neutral, NS: Not Supported

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