Proceedings of the 6th Asia-Pacific Structural Engineering and Construction Conference (APSEC 2006), 5 – 6 September 2006, Kuala Lumpur, Malaysia

COPING WITH EXTREME EVENTS IN THE BUILT ENVIRONMENT: ICT FOR DISASTER MITIGATION AND COLLABORATION

Aysu Sagun[1], Chimay J. Anumba[2], Dino Bouchlaghem[3]
Loughborough University, Department of Civil and Building Engineering, LE11 2TU, UK [1,2,3]
E-mail: *A.Sagun@lboro.ac.uk* [1], *C.J.Anumba@lboro.ac.uk* [2], *N.M.Bouchlaghem@lboro.ac.uk* [3]

ABSTRACT: Developments in Information and Communication Technology (ICT) have made great contributions to the quality of life, enhancing information flow and exchange and thereby collaboration in many fields such as education, design, construction and management. This paper is concerned with the use of ICT for disaster management and mitigation for a more secure and safe built environment. The management of disasters requires a continuous cyclic process that involves the pre-, during and post-disaster activities to mitigate the impact of unexpected natural and man-made disasters on people and the environment. It is a highly collaborative process involving governments, disaster management organizations, responders, the construction sector and the general public. An extensive research on the purpose and capabilities of available technologies is important to find out the most suitable ICT solutions so as to avoid failures and inconsistencies caused by misplaced reliance on technology. The integration of various ICTs with each other and other technologies is even more effective for the collaborative process of disaster management. In this paper, a conceptual framework is introduced to integrate ICTs in disaster management for the mitigation of the impacts of disasters on the built environment. Within this context, the deployment of ICT tools in disaster management is explored. Finally, the tools and technologies defined for two disaster case studies are presented and future research areas are discussed.

Keywords: Information and Communication Technology, disaster mitigation, safety and security

1. INTRODUCTION

Millions of people suffer from various types of natural or man-made disasters all around the world. Disasters can be defined as incidents that occur when hazards affects the vulnerabilities of populations or areas, resulting in permanent changes to people, the economy and the built and natural environment. Disasters can be classified under two main headings based on their origin as natural or man-made disasters. Natural disasters are unplanned events that take place as a result of a natural process such as extreme changes in the earth, weather or climate such as atmospheric (tornadoes, hurricanes, cyclones, hailstorms, freezes, wind storms), hydrologic (tsunamis, floods, droughts, coastal erosions), tectonic (earthquakes, landslides, volcanoes) or wild fire disasters. Man-made disasters occur as a result of the interaction of people with the environment or human systems. They are related to inhuman activities (terrorism, war, violent strikes), hazardous materials (chemicals), technology (utility failures, virtual network attacks), nuclear power (nuclear radiation escapes), biological (epidemics in humans, animals or plants) and large-scale explosions and fires.

As an unexpected and impulsive event, it is not possible to completely avoid disasters. However, being prepared for the potential threat of a disaster and efficient use of resources can help to minimize the risks and the effects. In this regard, the concept of Disaster Management and Mitigation (DMM) has been a promising area of research with the increase in occurrence of natural and man-made disasters such as floods, earthquakes and terrorist attacks. DMM is a cyclic and collaborative process in which the gathering, organization and dissemination of information and data are critical. It is very important to pass the right information, in the right amount, at the right time, from the right place, to the right person. As Michalowski (1991) stated, disaster management requires flexibility in decision support and ability to respond to varying situations because the scale of the residual effects varies according to the type and scale of the disaster.

Quarantelli (1997) claimed that in order to prepare a successful disaster management plan , the focus should be on the generic planning process rather than on the completion of a standard written document. It is neither possible to fully predict nor to eliminate the effects of a disaster. There is a significant need to increase mitigation activities and studies for disasters because the increase in population and built assets make the needs and requirements of the response and relief activities more expensive and complex (Oberoi and Thakur, 2005). Mitigation can simply be defined as long-term loss reduction. The activities of mitigation include incorporation of current DMM plans and predictions for new circumstances during a disaster. The mitigation efforts vary at different levels of DMM. Hamilton (2000) claimed that it is essential to combine hazard assessment with vulnerability data in order to assess risk, which would be helpful to create a foundation for mitigation actions. Gow (2003) agreed that the concept of vulnerability was an important factor for mitigation actions. Mitigation is also a part of risk management (Smith, 2001). The assessment of risks and hazards occurs prior to defining mitigation actions.

Information and Communication Technologies (ICT) play an important role in DMM. ICT enable further opportunities for more practical and vital activities of people in addition to the common use in business, education and entertainment. They facilitate the process of information flow and coordination, enhancing disaster planning, mitigation and management. This paper explores information flow and use of ICT in DMM. The next sections discuss ICT usage in DMM, using two detailed case studies on the integration of ICT in flood and terrorism management and mitigation. The final section includes a brief discussion and conclusions.

2. INFORMATION FLOW IN DISASTER MANAGEMENT AND MITIGATION

Disasters are unstructured in scope (Scalem, et. al., 2005) and are unpredictable. In order to cope with the residual effects of disasters, a systematic organization of people, work labour and available resources is required. Stakeholders have divergent responsibilities at various levels in the physical scale: disaster site, local regions, national and international levels. There are several branches of information flowing in various directions during a disaster: within each participating organization, between organizations, from people to organizations, and from organizations to people. As the number of system users increases, it gets harder to ensure the adequacy of information flow. ICT systems should therefore be designed to accommodate the large volume of information required by the system users. The ICT system should minimize the risk of system failure, loss and delay of information among the parties.

The information flow in disaster communication is strictly different from routine information exchange as a result of the nature of the information and possible disruptions in the communication channels. There would be problems in the content and flow of information especially of the initial stages of a disastrous event. The common problems seen in information flow during a disaster are:

- Overload of Information;
- Dissemination of incorrect information;
- Dissemination of incomplete information;
- Constantly changing information;
- Conflicting information;
- Breakdown of communication channels;
- Information and communication chaos;

It is essential to respond immediately to personnel or victims involved in a disastrous event. However, clarification of the situation and the needs has priority over a quick response. Missing information or misunderstandings in disaster communication would hinder the success of response. The other issues that threaten successful disaster communication are related to being unprepared and the lack of a common language, communication channel or format.

3. USE OF ICT IN DISASTER MANAGEMENT

3.1 Introduction

ICT plays an important role in DMM but as stated in the CSTB Report (1999), misplaced reliance on technology could itself trigger the crisis. The relevant integration of various ICT with each other such as the World Wide Web, simulations and decision support systems can generate a more effective setting for DMM. The challenges in DMM and communication are usually related to information management, not technology.

The technology used during pre, during and post stages of a disaster should be reliable and disaster-resistant, avoiding any breakdown or chaos during any catastrophic event. During a disaster response, people tend to use the tools that they are familiar with, so integrating new IT solutions and tools in planning and training operations is necessary to familiarize people with the latest tools. DMM systems and tools should be developed in a user-centred approach that considers user characteristics and the tasks they carry out. The interfaces should be easily and effectively operable during a high-stress disaster situation. The usability of the interfaces, even by a person with minimal training should be easy because an emergent disaster situation would give no chance to find out how an interface works.

The integration or deployment of technology in DMM is not to be conducted at a single time but is an ongoing and recursive process for all the parties involved in the DMM process. It is hard for public safety organizations to keep pace with the rapid changes in ICT, as the adoption of new systems would take time and money. Higher costs, more resources are needed. Consistency in IT systems and equipments among collaborators is also necessary to carry out the coordinated work. Coordinated and synchronized acquisition plans are required for developments in integration of ICT with DMM.

3.2 Telecommunication Technologies

Telecommunication technologies provide communication through electronic transmission at a distance with fixed or mobile counterparts. Radio communication services are useful and widely used in DMM for detection, prediction, alerting and relief operations. Mobile technologies include the devices that are designed to be carried while in use such as mobile phones, PDAs and tablet PCs. Mobile technologies eliminate the place constraints in communication and information exchange but they have low memory and limited power compared to fixed and server-based systems. They also have a limited capacity for interaction because they are designed to be small portable devices with small keyboards or screens for input and output (Bailey, 2004). However, they can be helpful especially when the wired communications are destroyed or overloaded (ITU, 2005).

Mobile technology includes wireless applications as well as wire-line. Wire-line technologies require a lengthy planning and construction process and cannot be employed in urgent situations immediately (Midkiff and Bostian, 2000). Wireless technology has the potential to provide communication at all levels of DMM. It can enable easy and rapid of deployment of communication infrastructure because it does not require a physical connection. The most popular products of wireless technology are cordless computer peripherals and telephone sets, satellite TVs, Global System for Mobile Communication (GSM) mobile telephone systems, General Packet Radio Service (GPRS) for Internet with mobile phones, Enhanced Data GSM Environment (EDGE), Wireless Application Protocol (WAP) for Internet connection, and Global Positioning System (GPS) devices for drivers. Other wireless technologies include packet-based system Universal Mobile Telecommunications System (UMTS) broadband, smart phones for Web browsing such as i-Mode, or wireless networks. High speed connection provided by broadband wireless technologies such as 3G, Wi-Fi, and WiMAX enhance information exchange, communication and collaborative working through wireless networks in many fields of study such as management, education, and communication.

3.3 Space Technologies

Information about available resources, access to roads and damaged areas, required resources and disaster response operations should be available and accessible immediately during a disaster (Mansourian, et. al., 2005). Space technologies enable immediate data collection about these issues through the use of satellite systems. Geographical Information System (GIS) is used to detect, store, manipulate, assimilate, analyse, map and display geographically referenced earth information. It enables the construction of maps to identify and analyze natural hazards (Zhou and Heinlen, 2005). It can be used to set up a key resource for disaster mitigation by maintaining geographical data such as information about rivers, soils, geology and areas in risk for flooding (Smith, 2001). It also provides support to see the potential interactions of various elements by combining layers of information (Hill, 2005). Moreover, GIS can be used in carrying out search and rescue operations in a more effective manner by identifying areas that are disaster prone and zoning them accordingly to risk magnitudes. It is widely used to record and visualise the key information, enabling retrieval of inspection reports about the rescue site, directions to the nearest aid and equipment stations and warnings and notifications on hazards (Foltz and Brauer, 2005). It is possible to use GIS with other technologies such as Laser Scanning, which involves the use of laser technology to gather 3D data in space to represent the surfaces.

Another promising technology is a system of satellites and receivers called Global Positioning System (GPS). It is a practical tool for detection, mitigation, response and recovery because it can provide the initial input for emergency response modelling and simulation systems. It is used for defining and computing positions and locations on the earth and is applied in navigation and cadastral surveying studies. It can be used especially by the people or rescuers who are unfamiliar with a given neighbourhood. Hand-held GPS equipment would be extremely helpful for rescuers in destroyed sites (Foltz and Brauer, 2005).

Sensor networks can provide real-time data streams, as a basis for system identification and decision-making. They may be developed consisting of groups of heterogeneous sensors such as cameras, strain gauges, accelerometers, etc. (Elgamal, et.al., 2005). Since sensor networks involve inexpensive sensors at low cost installation, it is possible to use large quantities of sensors for wide areas. Remote sensing is used to gather information about a subject that is at a distance from the information-gathering device. It assist risk and vulnerability analysis, hazard zoning, mapping, disaster warning, tracking and monitoring and assessment. Some examples for remote sensing systems are weather radar, weather satellite, seismographs, and aerial photography.

3.4 Other Computer-based Technologies

Reducing the data to the most important and relevant is achievable when the models are included in disaster planning (Perkins, et. al., 2005). The tests conducted by simulations with ICT products enable predictions about the performance of the system/product in a real life situation. Modelling and simulation applications can be useful at pre-planning, predictions of possible damage, training for responders and public awareness and performance evaluation for reconstruction. Databases give opportunity to observe past experiences and applications as well as to follow the progress of recorded issues. The information needed about the disaster such as location, damage or any issue related to health, shelter and transportation can be accessed from the relevant database via a network connections. Network structures such as Wide Area Networks (WAN) and Local Area Networks (LAN), enable the sharing, exchange and dissemination of information. Grid technology in computing also enables users to share, select, and cluster large amounts and varieties of geographically distributed computational resources and to present them as a unique resource. This approach is effective in dealing with large-scale computer and data intensive computing applications allowing collaborative works and large-scale data analysis.

Internet provides rapid dissemination of the information to the whole world and act as a means of recording and archiving the data. It can also provide a means of collaboration among disaster management parties at different locations through collaboration or project management Web sites that provide personal/institutional virtual spaces connected to a common database to store and share data. Moreover, disaster or emergency management Web sites can be linked as a recommendation to form a disaster network. Raheja, et.al. (1999) claim that integration of GIS and the WWW would increase the use and accessibility of spatial data by gathering, analysing and using a huge quantity of data related to disasters with its user friendly interface. There are various protocols being developed to provide a common language and format for the exchange of information during incident response activities, based on XML format such as Simple Object Access Protocol (SOAP), UML eXchange Format (UXF), Common Alert Protocol (CAP) and Emergency Data Exchange Language (EDXL), Global Justice XML Data Model (GJXDM), Specific Area Message Encoding (SAME), and IEEE 1512 standards. It is possible to use more than one protocol and language to set up a system for information distribution. As Raymond (2004) stated, alerts can be sent to cellular phones, PDAs and computer screens by using the CAP and XACML (eXtensible Access Control Markup Language) together.

4. DEPLOYMENT OF ICT IN TWO SPECIFIC DISASTER CASES

4.1 Framework for the Use of ICT in DMM

It is not an easy process to provide the collaboration of a huge number of participants during a tense disastrous event. All the organizations and stakeholders involved in the process of DMM should react efficiently both in their individual responsibilities and coordinated activities. This exigency draws attention to the need for an efficient collaboration of stakeholders as well as efficient ICT systems to be used within and between the participating organizations. The development of a model for ICT usage in DMM requires the identification of actions, active agents and the tools for the process. The model is constructed according to the actions taken during DMM as summarised in Table 1. It is based on the interaction and hierarchy of three levels of disaster management in the UK, namely local, regional and national level (See Fig. 1).

Table 1. Actions at each stage of DMM

Pre-disaster	**During Disaster**	**Post-Disaster**
Research	Warning	Damage detection
Training	Data management	Data Management
Raising public awareness	Assignments for rescue operations	Archiving/Back-up
ICT integration	Rescue	Information dissemination
Collaboration between stakeholders	Collaboration between stakeholders	Collaboration between stakeholders

The vital issue that needs attention in the disaster management process is the quality of information. Most of the problems appear in the quality of information as defined in Section 2, especially at the initial stages of a disastrous event. Based on this, the model includes data filtering systems between the three main levels during information flow in the DMM process. The disaster Data Filtering Network (DFN) system is introduced to cope with the problems faced in the disaster management process. It has basically three functions as follows:

- Collecting the disaster-related data and information from the public, media and experts who are specialists and responsible for the specific types of disasters;
- Organizing the available data and using the filter to sort them out;
- Sending the necessary filtered final metadata, data and information to the next level.

In the first stage of the system all the data and information are gathered and categorized as direct, overlapping, conflicting and incomplete. Basically, DFN will enable reliability control and categorisation of information and data into two as “clear” and “unclear” as well as sorting from the most important to the least important. Moreover, there will be an archive of metadata and the data of clear and unclear information and the relevant data will be disseminated to the appropriate locations. Metadata include information about the data and information such as where and when it comes from. Categorising and sending the information as clear and unclear would facilitate the decision making process because the reliable information is highlighted. The unclear information can be wrong, or still incomplete. However, it is not appropriate to disregard the unclear information since they would include important clues about the contexts. The decision makers can further investigate or monitor the change of data inputs in time if an information that is classed as unclear is needed to support their decision making process. The responsibility for management and control of the DFN systems resides at the level it belongs to. However, any information/data that is required from any other level can be accessed through a restricted authorising system by specific authorities. The filtering processes are shown as “F” in bold squares in the model (See Fig 1).

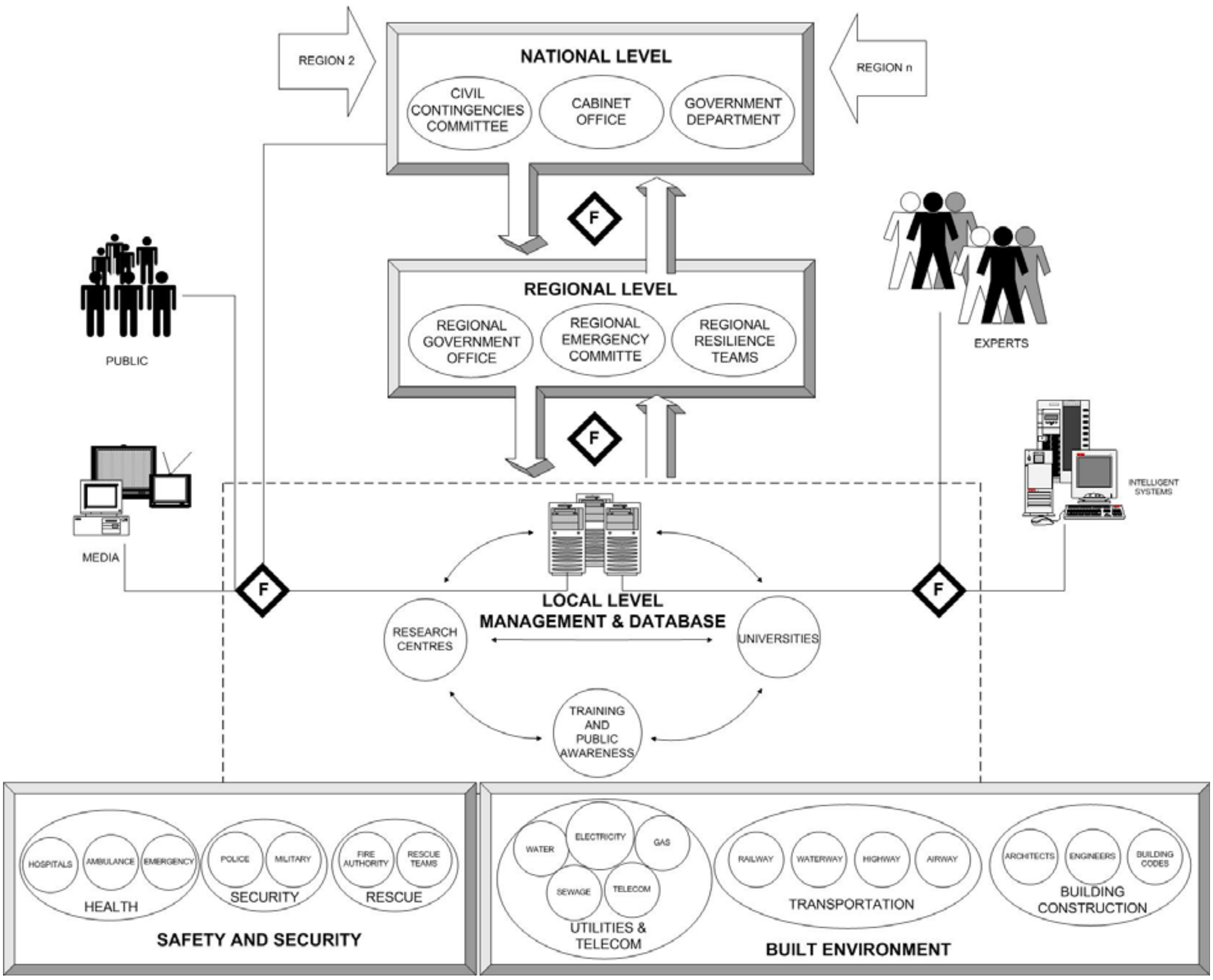

Fig 1. Intelligent Disaster Collaboration Systems (IDCS)

The model for *Intelligent Disaster Collaboration Systems (IDCS)* has three levels, namely Local Level, Regional Level and National Level. During a disaster, authorities at local level conduct the response activities. The regional and national levels collaborate to support the local level for decision making, management and resources. The local level authorities are categorised as safety and security authorities and built environment authorities. The main responsibilities of safety and security authorities are saving human life and providing the security. The built environment authorities are mainly responsible for the design, building, management, and safe and continuous service of buildings, transportation routes, building related services and utilities. All three levels have their own databases. Research centres, universities and other institutions for training the responders and public are connected to the local database to share knowledge and data for disaster related research. There is also information flow from the public, media, specific disaster experts to the local level management and database. All data and information collected from the stakeholders at local level are filtered and sent to the regional level. Regional level is informed by the local level management and database about the preparedness, response and recovery actions. The regional level supports the local level and takes all the responsibility in case of the failure or destruction at the local level. National level is informed by all regions in UK. It is the highest level and may take over the DMM process in case of failure or destruction of the regional level. It will also have the responsibility to provide the collaboration with the other countries about DMM issues.

It is not possible to predict the types, times and magnitudes of the disasters that a society may face beforehand. However, the risk analysis can show the possible type of disasters for particular locations based on environmental factors or social aspects. In this study, management and mitigation of flood and terrorist attacks are studied as examples of natural and man-made disasters that could occur in the UK. The tools, active agents and interactions are defined for each case in order to generate the ICT scenarios. The following section explains the scenario process within which the integration of ICT in DMM process is studied.

4.2 Case Studies

The scenario-based study started with the generation of disaster event scenarios. Next ICT scenarios are developed for each disaster event. The ICT scenarios reflect the possible solutions that can be constructed and implemented using the currently available and emerging ICT and tools. According to the ICT scenarios, a DMM network system is assumed to be constructed for the collaboration between stakeholders in DMM with a control centre in each city (local level). The ICT scenarios include advanced ICT approaches. Intelligent Disaster Collaboration Systems (IDCS) that operate at local, regional and national levels namely: Local IDCS (L-IDCS), Regional IDCS (R-IDCS) and National (N-IDCS) are involved. IDCS basically has three functions: to provide collaborative use of tools for monitoring and detection, collaboration during thinking process for decision making and collaborative use of resources for implementations. The IDCS is intelligent because it will have the ability to interpret the data received from the filtering system for distribution to the correct authority. It also will involve the following features to support the collaboration process:

- high information security;
- high speed data sharing;
- authorisation system;
- data interoperability;
- system interoperability;
- automatic data conversion (audio, textual, 2D, 3D);
- multilingual support;
- automatic text summarising.

In ICT scenarios, intelligent computer systems are involved in the collaboration process to filter the data and distribute it to the relevant parties.

4.2.1 Natural Disasters: Floods Mitigation and Management

Flood is a hydrological event caused by the overflow of water as a result of an excessive rise in the water level. There are various types of floods resulting from tides, heavy rains, rapid thaw of snow or ice or oceans waves on shore; some of them occurring slowly while others occur suddenly in a very short time. Climate change leads to flooding of coastal areas in UK as a result of higher sea levels caused by warmer temperatures, wetter winters and drier summers (DEFRA, 2005). It has physical, social, economic, and safety and security impacts on flooding (C-CIARN, 2006). The active agents at pre, during, and post stages of flood disasters are identified as stated in Table 2.

Table 2. Active agencies at pre, during, and post stages of flood management and mitigation

PRE	DURING	POST
DEFRA Environment Agency Met Office Regional Flood Defence Committees Flood / Weather Forecast Experts Police Forces Department of Health Health and Safety Executive British Telecom (BT) Utilities- water Utilities- drainage Construction managers Architects/Designers/Planners Engineers Material manufacturers	DEFRA Environment Agency Regional Flood Defence Met Office Committees Incident Control & Security Centre Police Forces Hospitals Ambulance loading points and services Casualty Centre Survivor reception centre Media Liaison Point TV/Radio broadcasting British Telecom (BT) Fire authority and services Transportation authorities - all	DEFRA Environment Agency Regional Flood Defence Committees Construction managers Architects/Designers/Planners Engineers Material manufacturers Flood / Weather Forecast Experts Utilities- all Transportation authorities- all TV/Radio broadcasting

The Utilities include water, electricity, gas and drainage authorities at regional and local levels. Transportation authorities include regional or local railway, highway, waterway and airway services. Although all the agents may have responsibility at all stages, they are categorised according to their most vital role in the mitigation process.

Flood management is strongly dependent on monitoring and estimation of critical developments. It requires a research process that involves (Mansor, et. Al., 2004):

- Hydrological assessments;
- Monitoring networks and information systems;
- Flood risk and damage assessments;
- Real-time flood forecasting and operational water management systems;
- River hydraulics and morphology;
- Land use and climate change studies.

The information needed in flood management is heterogeneous including water level and potential flooding support measures to identify risk to lives and goods, accessibility of locations, rescue resources, weather and regulations (Holz and Schley, 2005). Moreover, people need information on the situation, advice and instructions to be aware of what to do, where to go, and how to contribute. Satellite and sensor technologies play an important role in discovering the potential of floods by enabling the observation of the rainfall potential of storms and the condition of the soil. Flood planes and flood prone areas are also observed with remotely sensed imagery by flood mapping that uses images at pre-flood, peak flood and post-flood stages; and flood forecasting that observes the cloud patterns (Nirupama and Simonovic, 2002). Nirupama and Simonovic (2002) stated that satellite imagery is an effective tool for flood management because it provides detailed mapping for hazard assessment maps and hydrological models, and assists in the identification of the greatest risk areas as well as monitoring land use changes over the years. The comparison of the pre- and post-flood images are useful in determining the effects of flood on the environment. Sensors are also effective tools in flood monitoring, inundation mapping and the detection of soil moisture changes. Early warning equipment, such as flood gauges and landslide alarm fences, may be employed in identified disaster-prone sites. GIS technology also has an important role in flood management and can be used for mapping and monitoring flood plains, flood prone areas, and inundated areas for damage assessment, hazard zoning, post-flood surveys of river configurations and protection works, and also in search and rescue operations.

The tools used at each stage of the flood mitigation and management process are defined in Fig 2. As it is seen Figure 2, some of the technologies are specific for each DMM stage whereas others are used at more than one stage. Information security, information sharing, system interoperability, data interoperability, intelligent data management, Internet, auditing tools, multi-agent systems, multilingual support, decision support, mapping technologies, text summariser, visual data mining, mobile communication, wireless communication, remote sensing and GIS technologies provide common functionalities required at all stages of DMM process.

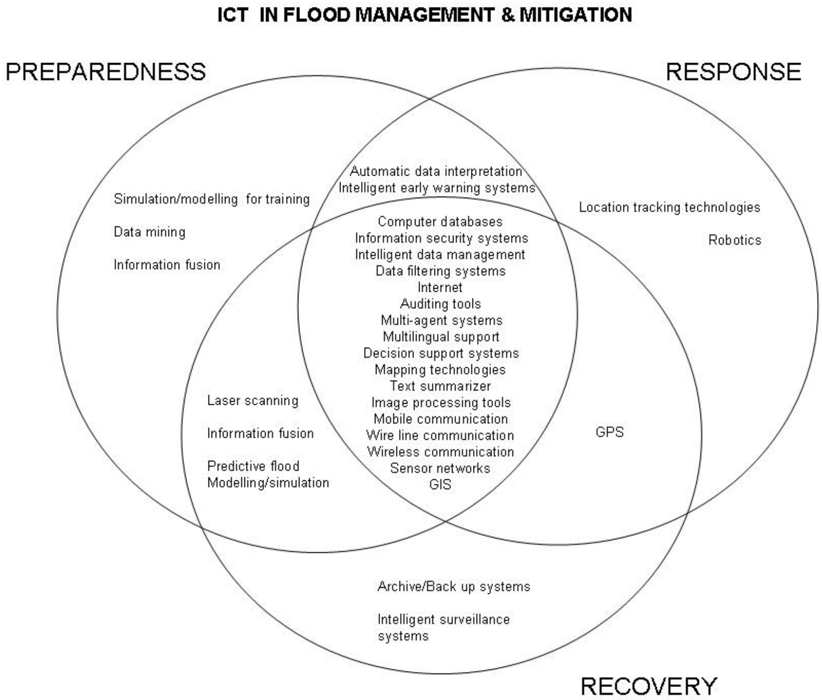

Fig 2. Use of ICT in management and mitigation of flood.

4.2.2 Man-made Disasters: Terrorism Management and Mitigation

One of the major threats to human life and environment today is terrorism. Terrorism can cause significant destruction to people and the environment using chemical, biological, radiological, nuclear, chemical, explosive and incendiary devices. Crucial locations that comprise the highest threat for terrorist attacks usually include critical crowded public spaces such as major highways, airports, train stations, bus terminals, subways, shopping malls, entertainment sites, financial centres, and stadia. Collaboration process for the management and mitigation of terrorism involves sharing of thinking processes as well as data and resources (Popp, et.al., 2004). Table 3 summarises the active agents that take most of the responsibilities at each stage. The Utilities include water, electricity, gas and drainage authorities at regional and local levels. Transportation authorities include regional or local railway, highway, waterway and airway services.

Table 3. Active agencies at pre, during, and post stages of terrorist attacks

PRE	DURING	POST
Ministry of Foreign Affairs Incident Control & Security Centre Police Forces Department of Health Health and Safety Executive British Telecom (BT) Media Liaison Point Construction managers Architects/Designers/Planners/ Engineers Material manufacturers Experts Users	Incident Control & Security Centre Police Forces Hospitals Incident Medical officers Ambulance services Casualty Centre Survivor reception centre Media Liaison Point TV/Radio broadcasting British Telecom (BT) Fire authority and services Transportation Utility services Home Office Ministry of Foreign Affairs	Police Forces Home Office Ministry of Foreign Affairs Construction managers Architects/Designers/Planners/ Engineers Material manufacturers Experts

The activities of terrorism management and mitigation include:

- Predicting intelligence and surveillance of targets and means;
- Preventing disrupt networks, contain threats;
- Protecting harden targets and immunize populations;
- Interdicting frustrate attacks, manage crisis;
- Responding and recovering damage;
- Identifying attacker to facilitate response.

A large international sporting occasion is chosen as a case for the man-made disasters for the scenario-based study because it would capture the attention of international terrorists. Three disaster event scenarios are created at different scales. Next, an ICT scenario is designed for each disaster event.

The policies and regulations of collaborating parties vary according to their functions and organizations being hierarchical or self organized. Therefore, the tools used in collaborative processes should be flexible to support organizations of various natures. The integration of ICT in this process involves the consideration and deployment of the collaboration tools (for information sharing, system interoperability and knowledge management); analysis and decision support tools (for data mining, social network analysis, event detection); foreign language tools (for multimedia and multilingual intelligence); pattern analysis tools; and predictive modelling tools. These technologies would enable allow search, query, and use of data as well as automatic extraction of entities and relationships from massive amounts of unstructured data to discover relationships and patterns between terrorist activities (Chen, et. al., 2004). The collaboration tools are useful for reasoning and sharing information to test hypotheses and to propose theories. ICT technology helps decision and policymakers to evaluate the effects of current or future policies and potential courses of action. Figure 3 illustrates the classes of ICT that are used and in development for terrorism management and mitigation according to their use at specific stages.

It is found that some of the ICT tools are used at only particular stage of DMM such as pattern analysis, robotics or technologies for back up systems, but most of them are used throughout the DMM process such as technologies for information security, interoperability and multilingual support as seen in Figure 3.

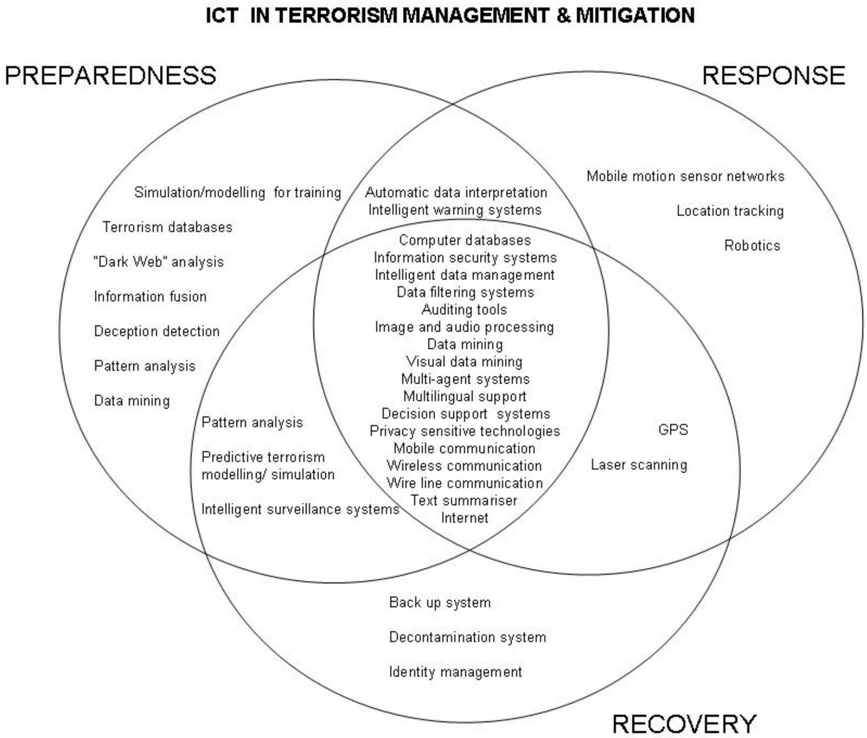

Fig 3. Use of ICT in management and mitigation of terrorism.

5. SUMMARY AND CONCLUSIONS

This paper has discussed the use of ICT in DMM. There are various information technologies available for different stages of DMM. In this study, the ICT tools for DMM were highlighted under three headings: telecommunication, space and other computer technologies. Next, the model being developed for the integration of ICT in DMM process was explained. The model is based on an Intelligent Disaster Collaboration System (IDCS) and a Data Filtering Network (DFN) that operate at local, regional and national levels. Further focus is on properties and tools used in flood and terrorism situations. These two disaster types were chosen, each as an example of a natural and man-made disaster, for scenario-based case studies. The outcomes of the study reveal the properties and differences in needs, requirements and ICT use in natural and man-made disasters.

Research on understanding the nature of natural and man-made disasters and hazards is obligatory for DMM studies. The research directions should consider the multi-disciplinary and multi-sector nature of DMM, including stakeholders from government, agencies and the public. Low-cost, high performance with high speed and storage capabilities is highly considered for developments on DMM models and tools. New frameworks and forms of communication and interaction among agents-agents, government-agents, citizen-government, agent-citizens that provide easier collaboration are required. In addition to the need for improving current technologies to support the DMM process more effectively and efficiently, there is a need to develop and introduce new collaboration methods and technologies to fill in the gaps in DMM activities and information flow.

References

Bailey, A. (2004) “Challenges and Opportunities for Interaction on Mobile Devices” *Satellite Workshop Robust and Adaptive Information Processing for Mobile Speech Interfaces.* Geneva, Switzerland August 28 – 29.

C-CIARN-Canadian Climate Impacts and Adaptation Research Network (2006) Web site. Viewed on January 2006, <http://www.c-ciarn.ca/landscapehazards/index_e.asp>

Chen, H., Wang, F.H., Zeng, D. (2004) “Intelligence and Security Informatics for Homeland Security: Information, Communication and Transportation” *IEEE Transactions on Intelligent Transportation Systems*, Vol. 5, No. 4.

CSTB: Computer Science and Telecommunications Board (1999) “Summary of a Workshop on Information Technology Research for Crisis Management” *National Research Council, Committee on Computing and Communications research to Enable Better Use of Information Technology in Government*, National Academy Press, Washington D.C. Viewed on November 2005, <http://books.nap.edu/html/itr_crisis_mgmt/>

DEFRA (2005) Department for the Environment Food and Rural Affairs Web Site. Viewed on January 2006, <http://www.defra.gov.uk/environment/climatechange/about/ukeffect.htm>

Elgamal, A., Yan, L., Fraser, M., Lu, J.& Conte, J. P. (2005) “Large- Scale Simulation and Data Analysis” *Proceedings of the 2005 ASCE International Conference on Computing in Civil Engineering.*

Foltz, S. & Brauer, B. (2005) “Communication, Data Sharing, and Collaboration at the Disaster Site” *Proceedings of the 2005 ASCE International Conference on Computing in Civil Engineering.*

Gow, G.A. (2003) “Canadian Telecommunications Policy and The National Disaster Mitigation Strategy:Observing Wireless Enhanced 9-1-1” PhD Dissertation. Viewed on November 2005, <http://www.sfu.ca/cprost/docs/Gow_dissertation.pdf>

Hamilton, R.M. (2000) “Science and Technology for Natural Disaster Reduction” *Natural Hazards Review*, Feb., pp.56-60.

Hill, A. (2005) “Information Technology & GIS Employment During an Emergency Event” *ESRI Professional Papers.* Viewed on November 2005, <http://gis.esri.com/library/userconf/proc05/papers/pap1024.pdf>

Holz, K.P. & Schley, F. (2005) “ICT-Support for Management of Emergency Situations in Flood- and Geotechnical Engineering” *Proceedings of the 2005 ASCE International Conference on Computing in Civil Engineering.*

ITU (2005) International Telecommunication Union Web Site. Viewed on November 2005 <http://www.itu.int/ITU-R/information/emergency/index.asp>

Mansor, S., Shariah, M.A., Billa, L., Setiawan, I. & Jabar, F. (2004) “Spatial Technology for Natural Risk Management” *Disaster Prevention and Management*. Emerald Group Pub., Vol.13, No.5, pp. 364-373.

Mansourian, A., Rajabifard, A., Zoeja, M.J. V.& Williamson, I. (2005) “Using SDI and Web-based System to Facilitate Disaster Management” *Computers & Geosciences.* Article in press, 2005.

Michalowski, W., Kersten G., Koperczak, Z. & Szpakowicz, S. (1991) “Disaster Management with NEGOPLA” *Expert Systems With Applications*, Vol. 2, pp. 107-120.

Midkiff, S.F. & Bostian, C. (2000) “Rapidly Deployable Broadband Wireless Communications for Emergency Management” *Center for Wireless Communications*. Viewed on November 2005, <http://www.diggov.org/library/library/dgo2001/DGOMAC/MEDIA/MIDKIFF.PDF>

Nirupama & Simonovic, S.P. (2002) ICLR Research Paper Series, No. 21. Viewed on January 2006, <http://www.iclr.org/pdf/Niru_report%20Simonovic.pdf>

Oberoi, S.V. & Thakur, N.K. (2005) “Disaster Preparedness in The Hills: Natural Hazard Modeling Using GIS and Remote Sensing” *Proceedings of the 2005 ASCE International Conference on Computing in Civil Engineering.*

Perkins, T. K., VanBlaricum, V., Bozada, T. & Pride, R. (2005) "Minimizing Data Requirements for Disaster Planning Using Integrated, Efficient Models" *Proceedings of the 2005 ASCE International Conference on Computing in Civil Engineering.*

Popp, R., Armour,T., Senator, T. & Numrych, K. (2004) "Countering Terrorism Through Information Technology" *Communications of the ACM*, March 2004. 47(3), pp. 36-43.

Quarantelli, E. L. (1997) "Research Based Criteria for Evaluating Disaster Planning and Managing" Viewed on November 2005, <http://www.udel.edu/DRC/preliminary/246.pdf>

Raheja, N., Ojha, R. & Mallik, S.R. (1999) "Role of internet-based GIS in Effective Natural Disaster Management" Viewed on December 2005, <http://www.gisdevelopment.net/technology/gis/techgi0030.htm>

Raymond, M. (2004) "WIRLED PEAS-World Information Resources, Localized Environment Distribution: Personalized Emergency Alerting System" Extreme Mark-Up Languages 2004, Montreal, Quebec.

Scalem, M., Sincar, A. K., Bandyopadhyay, S. & Sinha, S. (2005) "A Decentralized Disaster Management Information Network (DDMIN) for Coordinated Relief Operations" 9th World Multiconference on Systemics, Cybernetics and Informatics (WMSCI 2005), Orlando, USA, July 10-13, 2005. Viewed on November 2005, <http://www.iimcal.ac.in/research/adhocnet/Papers/53.pdf>

Smith, K. (2001) *Environmental Hazards: Assessing Risks and Reducing Disaster.* Taylor&Francis Group, New York.

Zhou, Y. & Heinlen, D. (2005) "Developing Natural Hazards Mitigation Plan with ArcGIS" *ESRI Professional papers*. Viewed on November 2005 <http://gis.esri.com/library/userconf/proc05/papers/pap1259.pdf>