THE COLLABORATIVE RISK ASSESSMENT ENVIRONMENT IN DISASTER MANAGEMENT

Matar Helal Alzahmi

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Matar Helal Alzahmi

School of the Built Environment
College of Science and Technology
University of Salford, Salford, UK

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Glossary of Terms and Abbreviations

AIC	Ambulance Incident Commander
AIMS	Atlas Incident Management System
AIIMS	The Australian Inter-service Incident Management System
AS/NZS ISO	Standards Australia /Standards New Zealand Standard Committee, ISO 31000:2009
CAD	Computer-Aided Design
CBSE	Central Board of Secondary Education
CCA	The Civil Contingency Act
CCS	Civil Contingencies' Secretariat
CCWM	Co-spaces Collaborative Working Model
CHT	Cultural Historical Theory
COA	Collaboration Oriented Architectures
COMAH	Control of Major Accident Hazards
CPG	Comprehensive Preparedness Guide
CPSAT	Civil Protection Self-Assessment Tool
CRED	Centre for Research on the Epidemiology of Disasters
CRIP	Commonly Recognized Information Picture
CRR	Community Risk Register
CSCW	Computer-Supported Collaborative Work
CT	Critical thinking
DCLG	Department of Communities and Local Government
EA	Environment Agency
EA	Enterprise Architecture
EM	Emergency Management
FEAF	Federal Enterprise Architecture Framework
FEMA	The Federal Emergency Management Agency
GeoVEs	Geospatial Virtual Environments
GIS	Geographical Information System
HCI	Human-Computer Interaction
HITS	High Integrity Telecommunications System
HMDs	Head-Mounted Displays
HPA	Health Protection Agency
HSE	Health and Safety Executive

IAP	Incident Action Plan
ICS	Incident Command System
ICT	Information Communication Technologies
IEM	Integrated Emergency Management
IFRC	International Federation of Red Cross and Red Crescent Societies
IT	Information Technology
JESIP	Joint Emergency Services Interoperability Programme
LAs	Local Authorities
LRFs	Local Resilience Forums
MCA	Maritime and Coastguard Agency
NHS	National Health Service
NIMS	National Incident Management System
NFPA	National Fire Protection Association
NRE	National Resilience Extranet
PCTs	Primary Care Trusts
RCG	Recovery Co-ordinating Group
RED	Resilience and Emergencies Division
SCG	Strategic Co-ordinating Group
SHAs	Strategic Health Authorities
TCG	Tactical Co-ordination Group
TOGAF	The Open Group Architecture Framework
UN-ISDR	United Nations - International Strategy for Disaster Reduction
VR	Virtual Reality
WAPMERR	World Agency of Planetary Monitoring and Earthquake Risk Reduction
3D	Three Dimensional

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Declaration

I declare that the research contained in this thesis was solely carried out by me. It has not been previously submitted to this or any other institute for the award of a degree or any other qualification.

Abstract

In the past century the occurrence of natural disasters and man-made disasters have steadily increased with a significant loss of life, damage caused to infrastructure and property, and destruction of the environment. There is much evidence that natural disasters are growing on a global level. Dealing with disasters demand the involvement of a range of agencies collaborating and making collaborative decision. This research has identified the need for a collaborative platform to bring together a variety of information to enable multi-agencies to prepare for disasters and to enhance the resilience of cities. Risk assessment is a crucial aspect within the activities of multi-agencies. Risk assessment enhances emergency planning which can then be tested by detailed appraisals and exercises. Whenever risk assessment is updated, plans are revised and additional tests are carried out. Risk assessment helps multi-agency planners decide what resource requirements they need and what multi-agency activities need to be planned collaboratively in order to prepare for disaster. The aim of this research is to investigate the nature of an interactive map that can enhance multi-agency team collaboration in the risk assessment process in disaster management.

This research uses the six-step risk assessment process used in Australia and New Zealand which is widely recognized as being good practice. These steps are Contextualization, Hazard Review, Risk Analysis, Risk Evaluation, Risk Treatment and Monitoring and Reviewing (Standards Australia/Standards New Zealand Standard Committee, AS/NZS ISO 31000:2009).

In this research, the characteristics of a suitable interactive map for risk assessment was defined in collaboration with the senior practitioners within a multi-agency team in the UK. Semi-structured interviews were conducted with the senior managers of Category 1 responders in The Greater Manchester Local Resilience Forum (GMLRF) to capture the requirements for a multi-agency collaboration platform. The outcome of these interviews were used to capture the characteristics and develop the a prototype of the interactive map that can support risk assessment. Once implemented, the validation of the interactive map prototype was conducted involving senior practitioners of stakeholders in the GMLRF development group. The experiment was held in the THINKpod in ThinkLab, at the University of Salford. A total of 23 senior practitioners took part in the evaluation experiment. After a demonstration of a scenario and using the interactive map, the participants evaluated the prototype as a group and then completed questionnaires that

featured range of open, closed and rating scale questions. These questionnaires were designed to evaluate the perceived effectiveness and impact of the interactive map on strengthening collaboration among the multi-agency teams during risk assessment. The outcome of the evaluation shows a good level of satisfaction among the practitioners. The overall result suggests that the professionals view the interactive map as a good platform to support collaboration multi-agency teams in risk assessment activity.

Chapter 1 – Introduction

1.1 Motivation

Over the past century the occurrence of natural disasters and man-made disasters has steadily increased with a significant loss of life, and destruction of the environment and infrastructure. Disasters appear to be increasing in both the rate of occurrence and in intensity (Sahani and Ariyabandu, 2003; Moe et al., 2007). As indicated by Warren (2010), there is much evidence that natural disasters are growing on a global level. In contrast to the 73 disasters reported during 1900 to 1909, 2,788 disasters occurred during 2000 to 2005 (Kusumasari et al., 2010).

Natural disasters can impact on regions' or countries' economies (e.g. destruction of buildings, roads, infrastructure, farms, loss of income, loss of jobs, weakening markets). As indicated by Van Westen (2013), there is a need to understand the problems that are triggered by disasters and the consequences of them, to study risk assessment and to prepare for disasters before they occur in order to mitigate and reduce the impact of disasters on people, property and the economy and to improve the response to each type of disaster. Such a need has given the impetus to collate and understand local risk levels and the vulnerability of cities through a technology platform that can integrate disaster related intelligence to support interactive risk assessment involving multi-agencies (Kolbe, 2005; Marincioni, 2007).

As described in the UK Emergency Preparedness Report (Guidance on Part 1 of the Civil Contingency Act 2004) from the Cabinet Office (2013c) Integrated Emergency Management (IEM) is a comprehensive approach to the prevention and management of emergencies which views these activities as a whole. IEM is made up of six steps. Emergency Preparedness relates to the first four steps which are anticipation, assessment, prevention and preparation, while Emergency Response and Recovery covers the final two steps which are response and recovery. The purpose of IEM is to increase and maintain resilience in order to meet a variety of potential challenges. A vital aspect of IEM is the need for multi-agency collaboration so that there is a common understanding across all agencies. In order to meet this need, this research focuses on a collaborative platform for risk assessment. It is hoped that this platform can then be used as the basis to support other phases such as anticipation, prevention, preparation, response and recovery management in the future.

The Emergency Preparedness Report from the Cabinet Office (2013c) also suggests that risk assessment should form the foundation for emergency planning and business continuity plans which can then be tested by detailed appraisals and exercises. When risk assessment is updated, plans are revised and additional tests are carried out. Risk assessment, therefore, has a clear knock-on effect on the subsequent steps in the IEM process: preparation and prevention. Risk assessment helps multi-agency planners decide what resource requirements they need and what multi-agency activities need to be planned collaboratively in order to prepare for disaster. In order to make sure that plans are appropriate for the risks in an area, such plans must be created by a risk assessment process which considers, evaluates and then prioritizes local hazards and threats and the risks that come with them. Technology plays an important role here as computer software modelling of this information can provide significant assistance in assessing risk (Gordon, 2002; Federal Emergency Management Agency, 2008).

Overall, the U.S. Department of Health and Human Services (2002) suggests that risk assessment is a vital component in the preparedness step because it increases the awareness of risks and thus enables superior mitigation and preparation. Moreover, it is argued that if a risk assessment is to be successful, then it must be understood and communicated properly. With this point established, the importance of risk assessment is clear. In short, preparedness is only as good as the risk assessment that produces the preparedness.

Risk assessment consists of multiple steps. This research uses the six-step risk assessment process based on the standard used in Australia and New Zealand which is widely recognized as being good practice. These steps are Contextualization, Hazard Review, Risk Analysis, Risk Evaluation, Risk Treatment and Monitoring and Reviewing (Standards Australia/Standards New Zealand Standard Committee, AS/NZS ISO 31000:2009).

The first step in this process, contextualization, is vital. It is important to give the many agencies involved a full picture of the characteristics of the local area and the local risk environment, such as an overview contextualization of social intelligence (such as the demographic, ethnic and social composition of the community); geographical distributions; the identification of vulnerable groups; the level of community resilience; an overview of the local environment and an understanding of local vulnerabilities; the characteristics of space (urban, rural, mixed); an overview of scientific sites; an overview of the local infrastructure (transport, utilities, business); an overview of the critical supply network and critical services (telecommunication hubs, health, finance, etc.) and an overview of potential hazardous sites (and their relationships with communities) or sensitive environmental sites (FEMA, 2010). This type of information can help the various agencies establish a collective understanding of the local risk level and make better decisions.

As noted, risk assessment supports multi-agency teams in achieving preparedness. As a result, collaboration in risk assessment is crucial. It has been argued by many scholars that the requirement for collaboration between agencies in disaster management is clearly an essential element in creating a more accessible and transparent service delivery system in any future disasters (GAO, 2002; McEntire, 2008; Kapucu, & Garayev, 2011). Williams (2002) identified collaboration as a process of give and take that provides space for the construction of solutions that no individual actor could achieve alone. Collaboration is the only practical method for dealing with the complex and interrelated problems that cross administrative and jurisdictional boundaries. Where collaboration does not occur, the result can be delays or inefficiencies, inconsistencies, or even ineffective decisions made at a crucial time. Indeed the reason for developing collaboration in the risk assessment process is to allow agencies to move towards a common understanding of the local risks and develop a common risk mitigation plan.

Many researchers have identified the need for a collaborative platform for multi-agencies to prepare for disasters. The need for a platform that can enhance collaboration and collaborative decision-making concerning risk assessment has been argued for in the literature (Van Westen, 2013). However, little research is evident on the exploration of the nature of such a collaborative platform (Van Westen, 2013). Fleischauer et al. (2006) noted that spatial mapping is often not implemented to its full potential. There are many possible reasons for this lack of technological support. Little research has been done on how best to incorporate cascading effects into risk assessment mapping and this suggests that more work needs to be done on how multiple hazards can be mapped in risk assessment. It is also argued that, in the main, advances in technology are not translated into a form that practitioners and stakeholders can use. This could be due to the complicated nature of the interactions between a user and the platform they are using (Van Westen, 2013).

Past research has concluded that a map system has benefits in the risk assessment process because it encourages proactive rather than just reactive thinking. Alexander et al. (2011) found that such a map needs to be interactive and allow the user to manipulate scenarios. The system needs to enable communication, the sharing of professional knowledge and be user-friendly. However, they suggested that more research is required into the kind of information and the level of information that can be included in such a platform (Van Westen, 2013; MacEachren, 2005). The main purpose of this research is to investigate the system characteristics of a collaborative risk assessment environment where agencies can work collaboratively in order to enable participants to visualise and analyse various risks through an interactive map environment.

According to UN-Habitat (2007), risk assessment can support decision-making and increase risk awareness among various agencies. Furthermore, the visualisation of existing and potential hazards, vulnerabilities, capacities and risks has a vital impact on the work of agencies, more so than traditional methods (Martin et al., 1997; Husdal, 2001). Therefore, there is an assumption that, by adopting a visualisation approach, agencies can perceive facts and evaluate various risks through visualisation techniques. Interactive visualisation in the risk assessment process can help agencies explore high-risk areas, assess the location of vulnerable people and vulnerable areas, and view the capacities and resources available for those at risk in order to lessen their vulnerability (Whiteman, 1998; Rashed and Weeks, 2002; Lagorio, 2001; Kraak, 2006; UN-Habitat, 2007). Furthermore, the creation of different visual scenarios can improve agencies' collective understanding of risk levels and of their capacities. Visualisation can also be used as a common language to facilitate communication amongst the various agencies in the risk assessment environment. Interactive visualisation is widely considered as an effective and preferable medium for communication compared to other established methods, such as paper drawings or static images. Three-dimensional visualisation increases perception and enhances the effectiveness of multi-agency decisions (Christie, 1994; Kolbe et al., 2005; Zlatanova, 2008).

The above discussion indicates that a collaborative environment is necessary to allow agencies to communicate and consult in order to have a common understanding of risks. The range of information that supports risk assessment needs to be visualised seamlessly so that the agencies coming from different backgrounds can easily understand the subject under view. An interactive map could be used as the basis for risk exploration during the risk assessment process (Slocum et al., 2005). However, the nature of an interactive map that can support collaborative risks' assessment by agencies is still not well understood. Therefore, the purpose of this research is to address the following research question: What are the keys functional characteristics of an interactive map that can enhance multi-agency team collaboration in the risk assessment process in disaster management? The research plans to identify the characteristics of an interactive map that can allow agencies to communicate their ideas, exchange information and engage in visual thinking.

1.2 Aim and Objectives

Aim

The aim of this research is to investigate the nature of an interactive map that can enhance multi-agency team collaboration in the risk assessment process in disaster management.

Objectives:

1. To analyse the risk assessment process and capture key stakeholders' views in risk assessment processes.
2. To identify the key functional characteristics of an interactive map that can enhance multi-agency teams' collaboration in the risk assessment process in disaster management.
3. To design the look and feel of an interactive map that can enhance multi-agency team collaboration in risk assessment processes in disaster management. This design specification will be used to implement a prototype of the interactive map, with the support of a skilled IT person.
4. To evaluate whether the enhanced features of an interactive map has the potential to strengthen collaboration between multi-agency teams in risk assessment processes.

1.3 Research Scope

Collaboration is a crucial central part of IEM in the UK. Many policies and frameworks have been adopted to support multi-agency collaboration, risk assessment and preparedness in response to disasters and the guidance followed in the UK demands extensive collaboration at national, regional and local levels. As indicated in Figure1.1

the focus of this research is on the local level and on the work of the local resilience forums (LRFs), taking the Greater Manchester Local Resilience Forum as an example. LRFs are groups made up of various response agencies and, as such, are the mechanism for multi-agency collaboration in the UK. The Greater Manchester Local Resilience Forum is ideal for the study of the effectiveness of implementing the interactive map prototype because of the effective collaborative working undertaken in the Forum; this can be further enhanced through the interactive map.

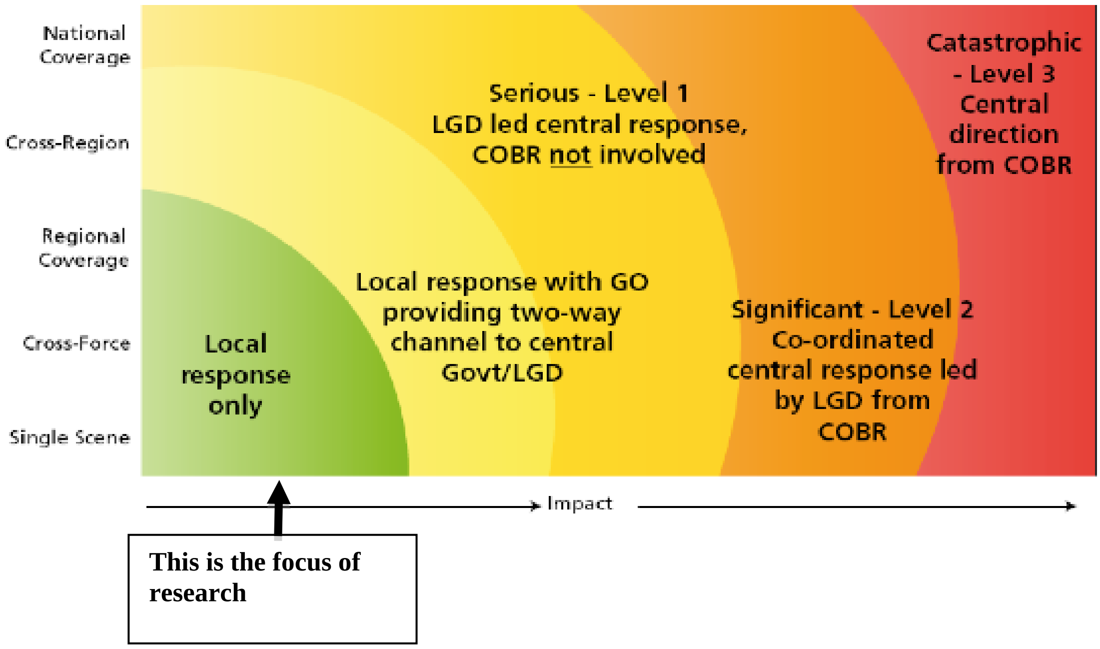


Figure1.1: Likely engagement of Central Government in emergencies occurring in England (Cabinet Office, 2013)

As shown in Figure 1.1, there are overlaps of interaction in the response for single scene local incidents up until incidents that require national coverage and which are catastrophic in nature. The researcher is investigating interaction, engagement and response arrangement between incidents, scene, impact, communication and different organisations at a local level and this further justifies the rationale for selecting Greater Manchester Local Resilience Forum.

1.4 The Research's Contribution to Knowledge

This research contributes to the new knowledge on collaborative working within disaster management. It specifically focuses on enhancing knowledge by the application of interactive maps in supporting the six-step risk assessment process and multi-agency collaboration. This research has conducted an in-depth analysis to identify the key stakeholders involved in the risk assessment process as well as the information required to and analyse in order to create a common understanding of the local risks by conducting a thorough risk analysis. This knowledge has been extracted from secondary data as well as primary data through interview of the Category 1 responders. This in-depth knowledge has been used to establish a viable interactive map that can visually present the risks that is required in the six-step risk assessment process. The overall construction of the interactive map is also a contribution to knowledge due to its design using different system views such as Team Member view, Information view, Process/Activity view and Data Visualisation view.

Finally this research collected and analysed feedback from the Greater Manchester Local Resilience Forum development group to capture "perceived effectiveness" of such an interactive map in supporting the risk assessment process as well as its potential for strengthening the collaboration between multi-agencies. Specifically, this research has contributed to knowledge as follows.

- The identification of functional characteristics on interactive map this knowledge could be used by the researcher community to develop different type of interactive maps using other technology such as virtual reality (VR) to support collaborative risk assessment involving key agencies in a city.
- The research conducted in this research has lead to the implementation and demonstration of an interactive map. The implemented interactive map illustration has the data required for the risk assessment could be combined, visualized and manipulated to build up a holistic view of local risk and help multi-agency to engage in decision during various stage of the risk assessment process.
- Data an "perceived effectiveness" of an interactive map from category 1 responder in supporting the six-step risk assessment process as well as multi-agency collaboration. This contribution gives confidence to the research community that the outcome is not just hypothetical but has been valid by the practitioners who are engaged in risk assessment in a major city.

1.5 Structure of the Thesis

This thesis is structured into the following chapters. Chapter 1 generally introduces the research's motivation and aim and objectives. It also presents the contribution to knowledge made by this research. The literature review is presented in Chapter 2 and Chapter 3, with Chapter 2 outlining the guidelines for disaster management and the organisational structure while Chapter 3 reviews various technological solutions for disaster management and the importance of an interactive map for risk assessment. The technologies that can provide multi-agency teams with an environment for the exchange of information, scenarios' presentation and a natural interface to present their ideas for risk assessment are also discussed in this chapter. Chapter 4 provides a theoretical foundation for this research, with investigations into the Activity Theory, Critical Thinking, models of team collaboration and a theoretical framework for this study. Chapter 5 provides detailed information on the research design used in this thesis. The chapter is structured under the following major headings: research philosophy, research approach and research techniques. Chapter 6 presents the outcome of the interviews conducted to identify the user requirements for the interactive map. Chapter 7 describes the possibilities for the design of the system and the conceptual framework of the design and the implementation of the system. Chapter 8 describes the evaluation of the interactive map prototype in order to test its ability to support collaboration and to enhancing multi-agency teams' risk assessment process. After this prototype was defined, it was necessary to provide a methodology for the evaluation of the system, which is described in Chapter 8. Chapter 9 presents the evaluation results collected during the evaluation experiment of the interactive map prototype, while Chapter 10 discusses the findings and their implications in reference to the literature. It also presents the limitations of this research. Finally, Chapter 11 presents an overall conclusion to this research and the extent to which it has achieved its aims and objectives and gives recommendations for future research in this field.

1.6 Summary

This chapter has described the scope of this research. It introduces the motivations for this research and the aim and objectives. Also, the structure of the thesis is outlined. The next chapter presents the background to disaster management cycles, the good practices undertaken by holistic approaches and the organizational structure of those organisations dealing with disaster management.

Chapter 2 – Analysis of guideline processes & the organizational structure in disaster management

2.1 Introduction

Throughout the past century the occurrences of natural and man-made disasters have steadily increased. With significant loss of life, damage to infrastructure and property and destruction of the environment, they appear to be increasing in both the rate of occurrence and intensity (Sahani and Ariyabandu, 2003). Indeed, there is significant evidence of the growth of natural disasters on a global level: for instance, in the years 1900 to 1909 natural disasters occurred 73 times, whereas from 2000 to 2005 this number increased to 2,788 (Kusumasari et al., 2010). As stated by Guha-Sapir et al. (2011) the number of victims increased to 232 million in the period 2001–2010, with most of the incidents caused by hydrological disasters.

2.2 Definition of a Disaster

According to Shaluf et al. (2003), there are many different definitions for a disaster but none of them are universally accepted yet. The reason that disasters are defined differently is because of the system by which they are explained. As indicated by Siriwardena et al. (2007), definitions of a disaster are based on technical, sociological, political and medical systems. Moreover, Eshgi and Larson (2008) stated that the definition of a disaster could vary based on the geographic, economic and political situations of disaster-prone countries. Disasters occur as the result of a combination of hazards, vulnerabilities and a lack of measures. Figure 2. 1 shows the elements that constitute disasters.

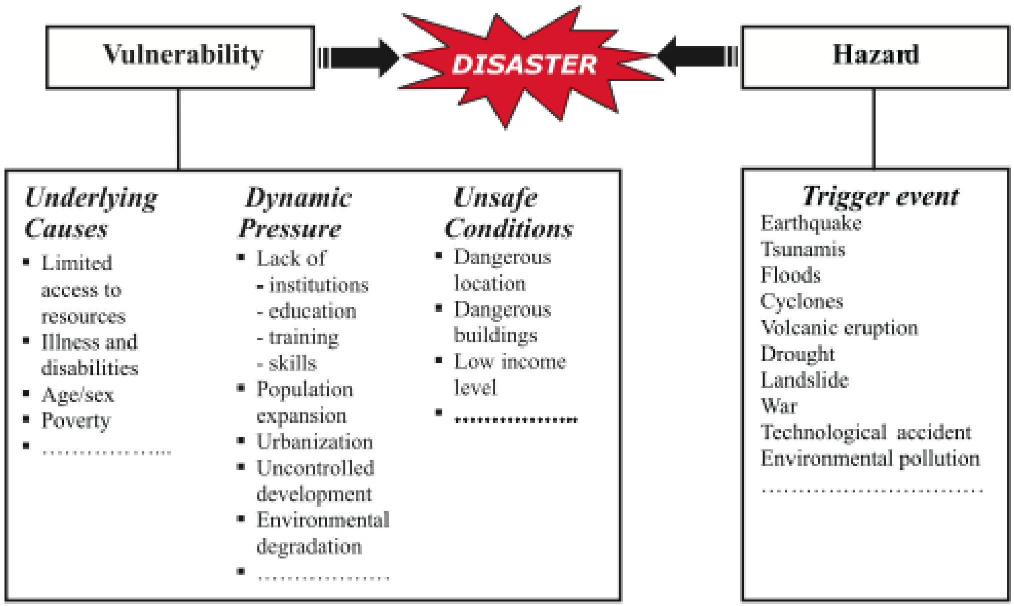


Figure 2. 1: The elements that constitute disasters. Source: CBSE (2006).

As seen in Figure 2.1, hazards constitute events that trigger disaster when vulnerability exists. According to authors such as Coppola (2007), “hazard is an action, event or object that maintains a positive likelihood of affecting man, or possibly has a consequence that may adversely affect man’s existence”. This indicate that the trigger events listed in Figure 2.1 (such as earthquakes, volcanic eruptions, landslides) will remain hazards with the potential to cause harm, until they interact with underlying causes, dynamic pressure and unsafe conditions (such as vulnerability) and then disaster will occur. This is perhaps why one of the most utilised definitions used in the area of disaster management is derived from the United Nations - International Strategy for Disaster Reduction (UN-ISDR). UN-ISDR (2009) states that a disaster is “a serious disruption of the function of society, causing widespread human or environmental losses which exceed the ability of the affected society to cope using only its own resources”. Parker (1992) also reviewed the subject area of disasters and described a disaster as “an unusual natural or man-made event, including an event caused by failure of technological systems, which temporarily overwhelms the response capacity of human communities, groups of individuals or natural environments and which causes massive damage, economic loss, disruption, injury, and/or loss of life”.

In addition, Haigh and Amaratunga (2010) stated that a disaster is an exceptional event with overwhelming loss of life and property. While all these definitions on disaster focus on a disaster’s impact and causes, the definition given by some authors focuses on the dynamic or manner of occurrence. According to Kelman and Pooley (2004) and Shaluf and Ahmadun (2006), disasters are sudden events which bring serious disruption to society with massive human, material and environmental losses which go beyond the capacity of the affected society to cope with using its own resources. Although the definition by Kelman and Pooley (2004) also emphasised the impact of disaster, the emphasis on the "sudden" occurrence of events that lead to serious disruption within society indicate the unexpected nature of what a disaster is. Therefore, the disaster context connotes an unanticipated event and occurrence wherein people are unaware of the time it will occur. While the sudden nature, impacts and causes of disaster will continue to be debated, the United Nations Environmental Programme (UNEP-APELL, 2003) has created the Centre for Research on the Epidemiology of Disasters (CRED) and associated websites to define disasters and record them within databases. CRED requires that, for any event to be recorded as a disaster in their databases, at least one of the following standards have to be achieved:

- Ten or more people reported killed.
- One hundred people reported affected.
- A call for international assistance.
- A declaration of a state of emergency.

These criteria help to clarify which data is recorded by CRED. They, however, fail in ensuring that disaster or any event that causes serious disruption within a society are well managed and their impacts prevented. This gap between the various definitions of disaster and the criteria for what constitutes a disaster emphasises the importance of this research which aims to investigate the nature of an interactive map that can enhance multi-agency team collaboration in the risk assessment process in disaster management. However, in order to do this, it is important to understand the types of disaster and their classifications so that assessing their risks can be better managed.

2.2.1 Disaster Type

As with the differences in defining a disaster, scholars classify disasters differently. According to Shaluf et al. (2003) and the International Federation of Red Cross and Red Crescent Societies (IFRC, 2012), the classification of a disaster depends on the cause of the disaster, whether natural or man-made. However, Shaluf and Ahmadun (2006) and

Shaluf (2007) have added a third type of disaster, namely a hybrid disaster that is caused by a combination of natural and man-made disasters. More detail is given in Table 2. 1. The first column indicates disaster type, the second column the sub-disaster name and the third column the name of the disaster.

Table 2. 1: Disaster types (Shaluf and Ahmadun, 2006; Shaluf, 2007)

Disaster type	Sub-disaster name	Name of disaster
Natural	Natural phenomena beneath the earth's surface	Earthquakes. Tsunamis. Volcanic eruptions.
	Topographical phenomena	Landslides. Avalanches.
	Meteorological/hydrological phenomena	Windstorms (cyclones, typhoons, hurricanes) tornadoes, hailstorms and snowstorms, sea surges, floods, droughts, heat waves/cold waves.
	Biological phenomena infestations	Infestations: such as locust swarms, mealy bug. Epidemics: such as cholera, dengue, ebola, malaria, measles, meningitis, yellow fever, HIV/AIDS, tuberculosis.
Man-made	Socio-technical technological disasters	Fire explosions: such as munitions' explosions, chemical explosions, nuclear explosions, mine explosions. Leakage. Release of toxic pollutions (pollution, acid rain, chemical pollution, atmospheric pollution). Structural collapse of physical assets.
	Transportation disasters	Air disasters. Land disasters. Sea disasters.
	Stadia or other public places' failures	Fire, structural collapse, crowd stampede.
	Warfare divided | 1.National	Civil war between armed groups from the same country, civil strikes,

	into:		civil disorder, bomb threats/terrorist attacks.
		2. International	Conventional war: war between two armies from different countries, sieges, blockades.
			Non-conventional war: nuclear, chemical, biological.
Hybrid	Natural and man-made events		Flood causing explosion(s) (fire, chemical explosion, etc.) Earthquake causing nuclear radiation, chemical explosion, etc.

Table 2.1 shows the relationship between the causes of disasters and the trigger points that translate a hazard into a major disaster (when there are severe consequences at a given location). Thus a better understanding is required of the relationship between a hazard (which has been explained as a potential event which has the likelihood of affecting man (Coppola, 2007)), vulnerability (which increases the impact of a hazard on man's existence) and resilience (Lofstedt and Boholm, 2005) (which is the inherent coping capacities for recovering from, and dealing with, disasters (Perrow, 2011).

2.2.2 Hazards, Vulnerabilities and Resilience

Regardless of a specific definition or classification, disasters occur when vulnerability and a hazard meet (Blaikie et al., 1994; Guha-Sapir et al., 2004). These terms are critical in the understanding of disaster management. In addition, UN-ISDR (2009) suggests that resilience is a third important concept.

2.2.2.1 Hazard

Hazard is explained by UN-ISDR (2009) as a "dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage". According to the International Federation of Red Cross and Red Crescent Societies (IFRC, 2012) hazards can be classified into two main types which are natural and man-made.

Natural hazards are naturally occurring physical phenomena which can be geophysical (earthquakes, tsunamis, volcanic activity), hydrological (avalanches, floods), climatological (extreme temperatures, drought and wildfires), meteorological (cyclones, storms/wave surges) or biological (disease epidemics, insect/animal plagues).

Technological or man-made hazards (complex emergencies/conflicts, famine, industrial/transport accidents) are events that are caused by humans and occur in, or close to, human settlements. These hazards can include environmental degradation and pollution (IFRC, 2012).

2.2.2.2 Vulnerability

Vulnerability is defined by the Central Board of Secondary Education (CBSE) (2006), as "the extent to which a community, structure, services or geographic area is likely to be damaged or disrupted by the impact of particular hazard, on account of their nature, construction and proximity to hazardous terrains or a disaster prone area". McEntire (2001) classified vulnerability into the following categories: physical (inappropriate and weak construction of buildings), social (restricted education, including insufficient knowledge about disasters), cultural (public indifference about disaster), political (limited number of institutions that have knowledge of disasters), economic (few resources that are important in preventing disasters like planning and management) and technological (the lack of using appropriate technology to mitigate the impact of disasters).

2.2.2.3 Resilience

The term "resilience" is largely attributed to ecological systems and originated from within the body of ecological literature (Adger, 2000a; Gallopín, 2006; Holling, 1973). The term has been subsequently applied to a range of subject localities such as psychology, materials' sciences, economics, environmental studies and social sciences (Adger, 2000a; McDaniels et al., 2008). The discussion here is limited to the concept of resilience from a social sciences' perspective, addressing hazards, climate change and related disciplines.

Adger (2000) discussed ecological resilience from two perspectives: (a) the amount of disturbance a system can absorb before it changes its structure by changing the variables and processes that control its behaviour, and (b) the speed of recovery following a disturbance. Consequently, social resilience has been defined as "the ability of communities to withstand external shocks to their social infrastructure" (Adger, 2000). On a similar note, Carpenter et al. (2001) defined resilience as "the magnitude of disturbance that can be tolerated before a socio-ecological system moves to a different region of state space controlled by a different set of processes". Both these definitions infer resistance to disturbance as a key criterion of resilience. However, Carpenter et al. (2001) emphasised that resilience has the characteristics of: (a) the amount of change a system can undergo whilst retaining the same structure and function, (b) the degree to which a system is capable of self-organisation, and (c) the degree to which a system can build the capacity to learn and adapt.

In short, a disaster happens when a hazard in the environment affects an area which has vulnerability, for instance, a river flooding (hazard) affects a collection of houses built close to the river (vulnerability). The area is resilient to an extent to which it can recover from the effects of the flood. In this simple example, the area would have high resilience if it had flood defences which kept the water level to a minimum. In contrast, if no defences were in place then the damage would be extensive and it would take a long time to recover. The area would, therefore, have low resilience.

2.2.3 Disaster Management Definition and Cycle

The aim of disaster management is to reduce or avoid the potential losses from hazards, assure prompt and appropriate assistance to victims of disaster, and achieve rapid and effective recovery. Many different definitions exist for disaster management, amongst which is that of Deshmukh et al. (2008) who stated that it is an integrated process of planning, organizing, coordinating and implementing measures that are needed for effectively dealing with impact on people. As described by Clerveaux et al. (2010), the disaster management cycle illustrates the process and steps that should be followed in a disaster to reduce the impact on society, provide a fast response and ensure the best recovery from the consequences of disaster. Four phases presented by Alexander (2002) - mitigation, preparedness, response and recovery - have been widely used by policy makers, practitioners, trainers, educators, and researchers. Figure 2. 2 shows the disaster management cycle and illustrates the four phases.

Figure 2. 2: The disaster management cycle (Alexander, 2002)

The key phases of disaster management are identified - before the event - as mitigation/preparedness and - after the event - as response and recovery. Mitigation involves reducing or eliminating the likelihood or the consequences of a hazard and seeks to “treat” the hazard such that it impacts on society to a lesser degree (Alexander, 2002). As explained by Haddow et al. (2013) definition of preparedness as plans or preparations made to save lives or property and to assist the response and rescue service operations. This phase covers implementation/operation, early warning systems and capacity building so that the population will react appropriately when an early warning is issued. According to the National Fire Protection Association (NFPA, 2007,) response is “immediate and ongoing activities, tasks, programmes, and systems to manage the effects of an incident that threatens life, property, operations, or the environment. Response activities may include the preservation of life, meeting basic human needs, preserving business operations, and protecting property and the environment.” Alexander (2002) explained recovery as returning victims’ lives back to a normal state following the impact of disaster consequences. The recovery phase generally begins after the immediate response has ended and can continue for months or years thereafter.

2.2.4 Summary

The preceding sections defined a variety of disasters that can be divided into the categories of natural, man-made and hybrid. Connected to each of these disaster types are the terms hazard (a danger in an area), vulnerability (the likelihood of this danger affecting the area) and resilience (the ability of the area to recover in the event of a disaster). These are core concepts in the disaster management cycle which is the cyclical process that reduces or avoids the effects of hazards, assists the victims of a disaster and aims to ensure effective recovery if a disaster occurs, taking place before, during and after a disaster event.

2.3 Holistic Approach to Disaster Management

Several well-known holistic approaches have been published in relation to disaster management. In economically developed countries like the USA and the UK, holistic approaches are taken. In the USA, a holistic approach includes four main phases of emergency management (EM): mitigation, preparedness, response and recovery (Tierney & Cigler, 2009). Meanwhile, in the UK the Integrated Emergency Management (IEM) consists of six steps; the first four stages are referred to as the Emergency Preparedness steps consisting of anticipation, assessment, prevention and preparation. The final two steps are referred to as Emergency Response and Recovery (Guidance on Part 1 of the Civil Contingency Act 2004, Cabinet Office, 2013c). The UK's holistic approach for emergency management is aimed at creating a connected, multi-agency response to emergencies at local level up to national levels. The holistic approach explicitly aims to boost the coordination and collaboration between multi-agencies and to ensure that new information is passed on and that responders at local and regional levels can maintain policies passed down from the central government. Since the aim of this research is to study risk assessment aimed at supporting emergency preparedness, the key approaches used in preparedness is discussed next. These holistic approaches are achieved through following specific guidelines which offer models of good practice.

The guidance presented in these approaches (which focus on collaboration among different agencies in preparing for different hazards) is important because different agencies may have access to different information that needs to be shared with other groups. In the USA, the authorities have adopted the concept of a Comprehensive Preparedness Guide (CPG) (Fugate, 2010) whereas the UK uses a risk assessment process based on the standard used in Australia and New Zealand (Standards Australia/Standards New Zealand Standard Committee, AS/NZS ISO 31000:2009). These guidelines are explained below. Within these guidelines, risk assessment plays a critical role because it forms the basis for emergency planning and so heavily influences the other stages of the model.

2.3.1 USA Comprehensive Preparedness Guide (CPG)

The CPG aims to ensure that the basic aspects of emergency plans are based on a thorough examination of a threat or hazard. The guidelines suggest that plans ought to be integrated and coordinated between agencies. The purpose of the guidelines is to build systematic planning into all phases of emergency management and emphasizes the need for the entire life cycle of an emergency to be accounted for. The guidelines call for a clear understanding of hazards, required capabilities and an outline of the roles and responsibilities of responders and stakeholders. They emphasize the need for a community to address its own specific context in terms of the risks faced and the resources available (Fugate, 2010).

The planning process is an important process in the preparedness phase. The process involves different sources of information which are brought together to create plans that can be used in an emergency and, therefore, increase preparedness. Collaboration between different agencies in planning is crucial because different agencies may have access to different information that needs to be shared with other groups in order to plan effectively. Moreover, planning is most successful when done as a team. When successful, the planning process allows multiple agencies to integrate in order to effectively prepare for disasters (Abbott, 2002). The model below in Figure 2. 3 shows the stages of the planning process. The model is intended to be flexible and adaptable for different emergencies. Each step will now be described in detail.

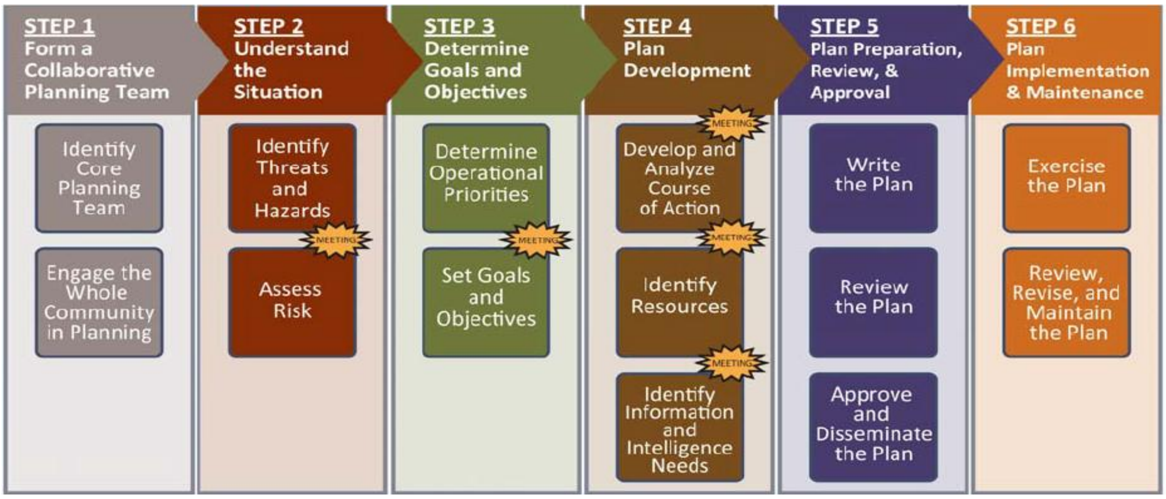


Figure 2. 3: The planning process (Fugate, 2010)

Step 1 – Form a Collaborative Team

It is widely suggested that, in order to effectively plan for emergencies, all agencies should be aware of their role and responsibilities. Research into emergency management has shown that a successful response to a disaster involves all participating agencies having a good understanding of their own role and the roles of other agencies. This can be best achieved during the preparedness stage. It is, therefore, important for agencies to collaborate in the planning process. This can be achieved by creating a planning team which includes representatives from different agencies. Collaboration at this stage will help improve relationships between agencies and, in turn, support creative and innovative planning. In this step, a number of guidelines can be followed by these agencies in order to effectively collaborate (Alexander, 2002). These are:

Plan ahead: Representatives from agencies need to know in advance the time and location of the planning meeting.

Provide information about team expectations: Representatives should be given a clear explanation of the purpose of the meeting and an outline of how their contribution will be important for the planning process. Essentially, representatives need to be motivated to attend.

Allow flexibility in scheduling after the first meeting: After the first meeting it may not be required that all members of the collaborative planning team attend all other meetings. Subcommittees could be established to complete the work, but should be given guidance about time frames and milestones.

Consider using external facilitators: Outside third-party organizations could be employed to manage the planning process and encourage collaboration between different agencies by mediating any disagreements.

With these guidelines in mind, the core planning team can be established. The leader of the team needs to be elected or appointed, usually from within one of the agencies involved in the collaboration. While initially the core planning team will be made up of representatives from the emergency agencies that are directly involved in risk assessment, the team can be supported by other experts from different departments or organizations who can provide different information and advice. Moreover, because emergencies and disasters affect communities, it is advisable to work with some representatives from the local community in preparing for disaster. Depending on the context, representatives could include people from social, religious and educational organizations, voluntary organizations and local infrastructure managers and planners. This will help the emergency planning team to better understand the local population and identify vulnerable places within the area. Representatives from the community can provide information about local hazards, the local population and their capabilities. A good relationship between the core planning group and the local community enhances trust which ultimately helps in preparing for disasters (Emergency Management Accreditation Program, 2007; Hewett et al., 2001).

Step 2 – Understanding the Situation

Once the core planning team has been established, they can begin to collect information relating to the threats and hazards in their area. Resources (such as money, equipment, manpower) allocated for emergency management also need to be considered. The information that needs to be collected is varied and includes the potential risks in an area and how the geographical features of the area could affect these risks. Furthermore, the demographics of the human and animal populations and should be gathered in preparing for disaster. This information can come from previous emergency planning work such as past threat assessments and mitigation plans. Also, local organizations like businesses and utility companies can provide information and guidance. Government and historical records can also be used to gather information which will help the planning group fully understand the situation (Federal Emergency Management Agency, 2008).

After the information has been collected, it needs to be organized and stored in a way that can be used effectively by the planning team. The risk analysis process organizes information about threats and hazards according to the following factors:

1) Probability or frequency of occurrence.
2) Magnitude (the physical force of the hazard).
3) Intensity/severity (expected damage or impact that could be caused).
4) Time available for warning.
5) Location of the incident.
6) Potential size of the area affected.
7) Speed of the impact (how quickly a disaster will affect the community).
8) Duration (how much time the incident will last).
9) Cascading effects (one impact causing another impact).

The risk assessment allows the planning team to decide which threats and hazards should be given priority. In turn, this helps them decide what resource requirements they need and what multi-agency activities need to be planned collaboratively in order to prepare for disaster. Planning teams may take different approaches and employ different techniques to assess the risk using this information. Methods include mathematical approaches, qualitative ratings (high, medium, low) and the use of index numbers (number scales like 1-10, 1-5 or 1-3). Computer software modelling of this information can also be a significant help in planning to assess risk (Gordon, 2002; Federal Emergency Management Agency, 2008).

Step 3: Determine Goals and Objectives

After understanding the situation and prioritising the most important threats and hazards in an area, the collaborative planning team has to outline what they would want to achieve in an emergency situation. This effectively means defining what it would mean for an emergency response to be successful, given all the information they have acquired about the size and scale of the threat.

This is achieved by first imagining a disaster situation by drawing on the information gathered in the previous step to create a scenario. With the correct information collected, this scenario will give a realistic simulation of the entire life cycle of a disaster and its impact on the community. Using realistic scenarios, the planning team can collaborate to identify their common vision. This common vision incorporates the goals and objectives of the agencies involved. In order to achieve these goals and objectives, the agencies need to understand their own role and responsibilities and those of the agencies with which they are collaborating. For example, the vision in an emergency could be to save lives and prevent damage to property. The related goal could be to evacuate a population as quickly as possible. The more specific objective could, therefore, be to evacuate a certain number of affected people in a certain amount of time. By clearly defining goals and objectives, the multiple agencies involved in emergency planning can ensure that they achieve their common vision (Federal Emergency Management Agency, 2008; Hewett et al., 2001).

Step 4: Plan Development

With the goals and objectives defined, the planning stage is required to create solutions for meeting them. The planning team should aim to generate and compare multiple plans. As in Step 3, this is achieved by imagining a scenario and its progression, including the actions and decisions that would need to be taken in the event of such a situation. The planning team needs to visualize the scenario using different tools. This can be done using, for example, a white board or a notice board but specialized computer planning software can also be employed to enhance the visualization and therefore the planning process.

During this part of the planning process, a number of activities are involved. Typically, a timeline is established in which the events that could take place in a scenario are given a chronological order. Then the scenario is depicted by adding information, developed in the previous step, to the timeline. Next, decision points are identified and depicted on the timeline. This means determining when key decisions will need to be taken during the scenario. After this, the operational tasks need to be depicted on the timeline by asking some basic questions about the nature of the task, the responsible parties, the resources available and the expected effect of the task. Planners then need to make a decision about what action they will take by analysing the costs and benefits of each possible response in relation to the objectives they have defined (Quarantelli, 1995; O'Leary, 2004).

Once the planners have chosen a course of action, they have to assess their resources and capabilities. Initially, planners tend to identify the resources needed to carry out their plan regardless of the availability of these resources. Subsequently, their requirements should be matched to the resources that are available to them. Using this matching process, shortfalls can be identified. A list of resources that are lacking can then be produced. This list can then be passed on to central government, other partners or private businesses to fill the gaps in resources. Similarly, the facilities (for example, hospitals and shelters) available in an emergency need to be considered. The effect that a disaster might have on these facilities needs to be taken into account. Resources and facilities have to match the geographical characteristics of an area. These considerations are put together to create a capability estimate which is a description of all the capabilities (such as staff, logistics and communications) and resources available to deal with a disaster. The capability estimate can be delivered in a number of ways including tables, written documents or presentations (Gordon, 2002; Alexander, 2002).

Alongside the identification of resources is the identification of the information required during such an event. The planning group need to identify what information will be needed at different stages of the scenario, prior to decision points. Each agency requires specific information about the situation on the ground in order to fulfil their responsibilities and make informed decisions during an emergency. In short, the multi-agency planning team needs to define what resources agencies will need and what information they will need (O'Leary, 2004; Perry and Lindell, 2007; Federal Emergency Management Agency, 2008).

Step 5: Plan Preparation, Review and Approval

The purpose of this stage is to take the planning done in the previous steps and use it to produce a final, definitive plan. The plan is drafted and redrafted collaboratively to produce a final version with which the team is happy. This can then be distributed to other parties within the multi-agency response for their input and comment. A set of criteria can be used to assess the suitability of the plan. The adequacy, feasibility, acceptability, completeness and legal compliance of the plan need to be considered during the review of the plan. The final plan is then checked against legislation to make sure that it meets legal requirements before finally being communicated to all the agencies involved in disaster management. Ultimately, it will be their responsibility that the plan is carried out (Perry and Lindell, 2007; Federal Emergency Management Agency, 2008).

Step 6: Plan Implementation and Maintenance

After members of the planning team have agreed the plan, it then has to be distributed to the managers of the agencies involved who are then tasked with training their staff to implement it. The effectiveness of the plan and the training that is undertaken can be measured using a combination of training events, exercises and real world incidents. These test whether the plan has achieved its goals or not. It is important that the plan is maintained and updated with new information regularly by the team (National Response Team. 2001; Perry and Lindell, 2007).

2.3.1.1 Summary

The steps outlined above could be matched to the overviews of a collaboration platform. Such a platform would allow the multi-agency planning team to navigate the planning process. It would provide a means to create and maintain relationships between members of the multi-agency planning team. It would also enable users to collaboratively share information relating to threats and hazards and use this to assess risk. Moreover, it would support collaboration so that team members can arrive at goals and objectives that would help them achieve a common vision. In addition, such a collaboration platform would allow users to collaboratively draw on all their information to simulate disasters and develop plans using scenario-based planning. Finally, it would provide a tool for its users to test their plans and preparedness. Ultimately, the multi-agency planning process is a lengthy, complex and potentially expensive one. Therefore, a platform that can create a collaborative visual environment could support and simplify the process and enable multiple agencies to collaborate in order to share information, build comprehensive risk models, model hazards and their dependencies, test their preparedness, simulate and visualise disaster impact, and communicate and collaborate in developing better resilience cities.

2.3.2 UK Risk assessment process

The six step risk assessment process used within the UK's IEM guidelines is based on the standard used in Australia and New Zealand which is widely recognized as being good practice (Standards Australia/Standards New Zealand Standard Committee, AS/NZS ISO 31000:2009). Figure 2.4 below illustrates the six steps. A brief description of each of these stages is presented.

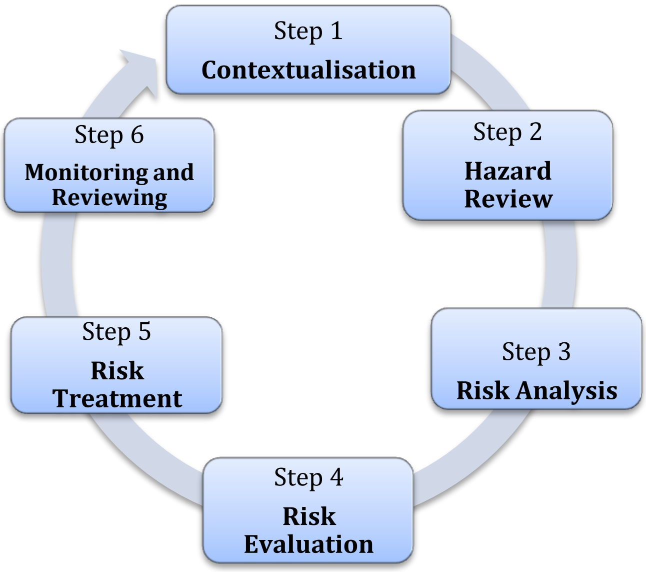


Figure 2.4: The six-step risk assessment process (Cabinet Office 2012, Local responder risk assessment of Emergency Preparedness).

Step 1: Contextualisation

The standard suggests that local responders should describe the characteristics of the local area that will influence the likelihood and impact of an emergency in the community. This would help multi-agency teams to understand the context and to identify the vulnerability and resilience of the area to emergencies. To achieve this, multi-agency teams should identify a number of aspects within their area. Firstly, there needs to be an exploration of various social information (such as the demographic, ethnic and social composition of the community, the geographical distribution, identification of vulnerable groups, level of community resilience). Secondly, multi-agency teams need to explore the local environment from a physical, rather than social, point of view. This involves understanding the local vulnerabilities, the characteristics of the space (urban, rural, mixed), the existence of other notable sites like ones of scientific interest. Thirdly, multi-agency teams have to explore the local infrastructure (transport, utilities, business), the critical supply network and critical services (telecommunication hubs, health, finance, etc.). Finally, multi-agency teams should undertake an exploration of potential hazardous sites and their relationships to communities or sensitive environmental sites. All these activities would help multi-agencies to understand the likelihood of, and the impact of, hazardous events in the local area (Cabinet Office 2012, Local responder risk assessment duty of Emergency Preparedness).

Step 2: Hazard Review

Hazards that present significant risks are identified on the basis of experience, historical data, research or other information. A hazard review should identify a large set of national hazards and then should review which of these could potentially affect a given area in a set timeframe. These hazards are imparted and discussed at multi-agency team meetings with a view to agreeing a list of hazards to be assessed. This hazard information helps members of multi-agency collaboration groups to make careful judgements on which hazards should be included in further assessment. This step could help multi-agency teams to capture experience, intelligence and research data and communicate them to others during hazard review meetings (Cabinet Office, 2012).

Step 3: Risk Analysis

The purpose of this step is to consider the likelihood of, and the outcome and impact of, a hazard. Likelihood is estimated within a set timeframe and a rationale for its assessment is provided. This work can be divided and shared depending on the organisation of a multi-agency group. What is most important is that all the relevant information and expertise is shared and communicated effectively. Input from all relative groups, including those that are outside the multi-agency team, should be taken into account. The simple definition of risk analysis is estimating the likelihood of a hazard occurring (Cabinet Office 2012, Local responder risk assessment duty of Emergency Preparedness).

The process of analysing risk begins with an initial assessment of the probability of a hazard occurring and its probable consequences. While seemingly straight-forward, the process differs considerably depending on the nature of the agencies involved and their responsibilities. For instance, a multi-agency team made up mainly of representatives of the emergency services will usually have a responsibility to be open and informative to the public. Therefore, such teams are likely to consider risk analysis to be a more complex procedure than, for instance, a single private company would. Any organisation must base decisions about the structure and complexity of their risk analysis process on their organizational judgment. By their very nature, it is also likely that multi-agency teams will need to have a higher level of flexibility in their risk analysis procedures than single agencies. It is similarly important that multi-agency teams have robust systems in place to pass the outcomes of risk analysis on to the right team members and, in some cases, external stakeholders such as government and private enterprises (Cabinet Office 2012, Local responder risk assessment of Emergency Preparedness).

Step 4: Risk Evaluation

The production of a risk matrix is an essential part of the risk assessment process. The notion of risk is divided into four risk ratings (very high, high, medium and low). These are used to indicate the risk level of a given hazard. Figure 2. 5 below illustrates the ratings and gives a brief description of each stage. Members of a multi-agency team compare these results to the risk criteria and confirm or modify these assessments. Moreover, existing capabilities to deal with potential hazards and threats are highlighted. It is common for a particular individual/group within a multi-agency group to be given responsibility for making recommendations on risk priorities which are then discussed and approved by the wider group. Effective collaboration at this stage can help agencies in having a holistic view of hazards in their local areas (Cabinet Office 2012, Local responder risk assessment of Emergency Preparedness).

An essential part of risk evaluation is the creation of a 'risk matrix' which involves mapping risks by plotting them on a chart. This is undertaken by giving a hazard a score for both its likelihood and its potential impact. Likelihood scores take into account the characteristics of a given site and are accompanied by a brief rationale for the score. Impact scores also come with a rationale and outline factors such as estimated numbers of casualties, the length of time an area might be cut off from electricity, or the size of an area that might be contaminated by a toxic substance. Different formulas are used by different emergency management teams to arrive at an overall place on the risk matrix. For instance, a risk matrix may place slightly more importance on the impact of a hazard than its likelihood. While different formulas and weightings can be used, there must be internal consistency. A multi-agency team should apply the same risk matrix repeatedly, so that results can be easily compared (Cabinet Office 2012, Local responder risk assessment of Emergency Preparedness).

In giving a numerical value as an output, the use of a risk matrix gives a clear, repeatable method for risk evaluation. In addition, it gives a clear way of communicating information about risks which can be passed onto relevant members of a multi-agency team or on to external groups like the government, private businesses, charities and public in a given area.

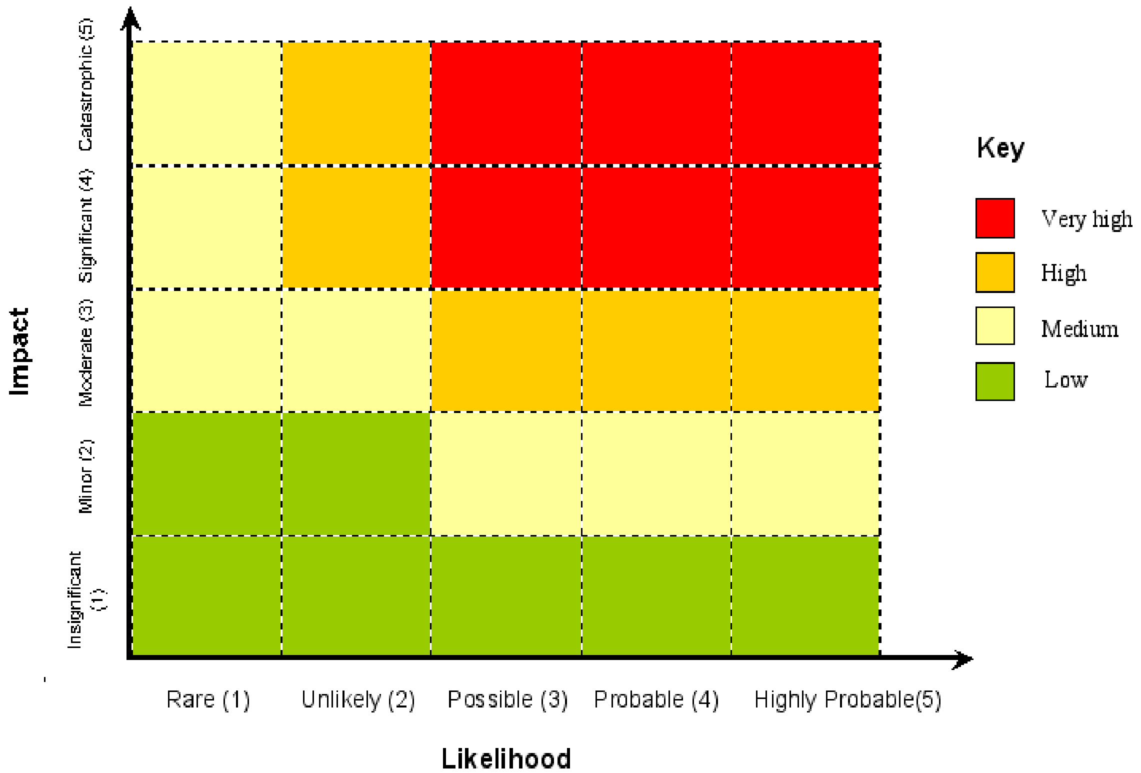


Figure 2. 5: Risk rating matrix (Cabinet Office 2012, Local responder risk assessment of Emergency Preparedness).

Definition of risk rating

Very High (VH) Risk - these are classed as primary or critical risks requiring immediate attention. They may have a high or low likelihood of occurrence, but their potential consequences are such that they must be treated as a high priority. This may mean that strategies should be developed to reduce or eliminate the risks, but also that mitigation in the form of multi-agency planning, exercising and training for these hazards should be put in place and the risk monitored on a regular frequency. Consideration should be given to planning being specific to the risk rather than generic.

High (H) Risk - these risks are classed as significant. As with those in the VH risk category, they may have high or low likelihood of occurrence, but their potential consequences are sufficiently serious to warrant appropriate consideration (after those risks classed as 'very high'). Consideration should be given to the development of strategies to reduce or eliminate the risks, but also mitigation in the form of, at least, multi-agency generic planning, exercising and training should be put in place and the risk monitored on a regular frequency.

Medium (M) Risk - these risks are less significant but may cause upset and inconvenience in the short-term. These risks should be monitored to ensure that they are being appropriately managed and consideration should be given to their being managed under generic emergency planning arrangements.

Low (L) Risk - these risks are both unlikely to occur and are not significant in their impact. They should be managed using normal or generic planning arrangements and require minimal monitoring and control unless subsequent risk assessments show a substantial change, prompting a move to another risk category (Cabinet Office 2012, Local responder risk assessment of Emergency Preparedness).

Step 5: Risk Treatment

Risk treatment has a number of stages, namely assessing the type and extent of the capabilities required to respond to hazards; identifying any capabilities in place, considering the capability gap and the extent of the risk; rating the risk priority; identifying additional treatments required to close the capability gap and to manage the risks more effectively, and identifying whose responsibility it is to provide treatment, etc (Cabinet Office 2012, Local responder risk assessment of Emergency Preparedness).

Step 6: Monitoring and Reviewing

This stage implies that risks should be monitored continuously and that the previous steps (1-5) should be repeated when new risks are identified. Monitoring and reviewing is intended to answer a number of related questions. Firstly, do the risks persist? Secondly, have new ones arisen? Thirdly, has the probability or impact of risks changed? More generally, this stage involves the reassessment of a team's risk priorities.

Feedback on the efficiency and effectiveness of previous decisions is provided at this stage. It gives multi-agency teams the chance to learn from successes, failures and near-failures. While risk management consists of the review of risks, this stage is effectively a review of risk management itself. It should take place at least once a year with a fundamental exploration of all aspects of the risk management process. Moreover, such an exploration should make sure that risks, and the activities put in place to minimize them, are monitored within an appropriate period of time. In addition, it should ensure that systems are put in place to alert the correct sections of the multi-agency teams when a new risk arises or changes take place to already identified risks (Cabinet Office 2012, Local responder risk assessment of Emergency Preparedness).

A theme throughout emergency management is the need for roles and responsibilities to be clearly defined and understood and this is no different at the monitoring and review stage. Part of this involves the efficient communication of information and experiences between different elements of a multi-agency team. This may be the ultimate responsibility of a team member or a specific role in itself. Effective communication is again key in sharing the results of the review and in the monitoring process, especially if the results are to be used to adapt and refine the overall risk management framework that a team operates within. Moreover, the outcomes of this stage can assist a team in refining its internal organization and improving its organizational culture (Cabinet Office 2012, Local responder risk assessment of Emergency Preparedness).

2.3.2.1 Summary

Having a six-step model for dealing with incidents in the UK (four of which are pre-incident stages) emphasises the need for a better interactive platform that can enhance collaboration between all agencies involved in pre-incident planning. The IEM approach to dealing with disaster is not the basic four main phases of EM as operated in the USA, but rather four interrelated steps that require continuous assessment and review of risks, (which is required for risks to be effectively managed (Lofstedt and Boholm, 2005)). For instance, the impacts of the 2007 summer floods and the 2014 winter floods are reminders of the inability of all stakeholders to interact in a way in which they are able to jointly engage in anticipation, assessment, prevention and preparation for identified risks such as a flood and its impacts. This gap in the implementation of a UK model and the challenge of being able to engage at the required level of interaction between agencies and stakeholders emphasises the relevance of a supportive and interactive platform for multi-agency team collaboration in the risk assessment process for dealing with disruptive incidents.

2.3.3 Summary

Overall, it is clear that the holistic approach to the four main phases of Emergency Management (EM) as used in the USA and the Integrated Emergency Management (IEM) peculiar to the UK, share commonalities. Both aim to provide an integrated approach and stress the importance of collaboration and coordination between multiple agencies. However, because the pre-incident steps in the IEM holistic approach are more in number than that of the EM four-phase approach in the USA, the cumbersome process of continuous interaction between multiple stakeholders within the risk assessment process can be challenging, if not almost impossible in some cases. The continuous impact of hazards such as floods in different cities across the UK indicate the need to enhance collaboration within multi-agency teams and their interaction concerning risks' assessment at the anticipation, assessment, prevention and preparation steps that lead to emergency response and recovery. Since this research uses the UK as a case study, the risk assessment process is critically examined within the context of the requirements for IEM, which also provides guidance and focus for this research.

2.4 Organizational Structures for Disaster Management

This section aims to identify and introduce the most well-known management system standards incorporating the well-organized management of incidents by integrating the facilities, personnel, equipment, procedures and communications that operate within a common organizational structure. Examples of such standards are the United States (USA) Incident Command System (ICS), the Australian Inter-service Incident Management System (AIIMS) and the United Kingdom organisational structure for disaster. The three countries use an ICS response model for responding. This is because, for risk assessment to be effective and in order to ensure effective risk mitigation, reduction, elimination and prevention (Lofstedt and Boholm, 2005), hazards which have the likelihood of causing severe consequences to society ought to be examined before they actually cause harm to the public (Perrow, 2011). Therefore, this section focuses on the organisational structure in the UK, but starts with drawing the context from the systems and structures in the USA and Australia which are countries with a similar level of development.

2.4.1 USA Incident Command System (ICS)

ICS is a management system which allows effective and efficient management of domestic incidents (FEMA, 2008). It is a standardized management tool that is applicable to a wide range of emergencies, from small to large (FEMA, 2008). The system:

- Represents the standard for emergency management across the United States (USA) and is seen as "best practice."
- May be used for planned events, natural disasters and acts of terrorism.
- Is a key feature of the National Incident Management System (NIMS) (FEMA, 2008).

ICS Organizational Structure

The organizational structure of ICS, as shown in the Figure 2. 6, determines how the roles, power and responsibilities are assigned, controlled, coordinated, and how information flows between the levels of management. Since ICS allows for organizational flexibility, the Intelligence/Investigations Function can be embedded in several different locations within the organization. All levels of the USA government use ICS, as well as many private sector and non-governmental organizations. ICS is applicable across disciplines and is normally structured to facilitate activities in five major functional areas: command, operations, planning, logistics, and finance and administration.

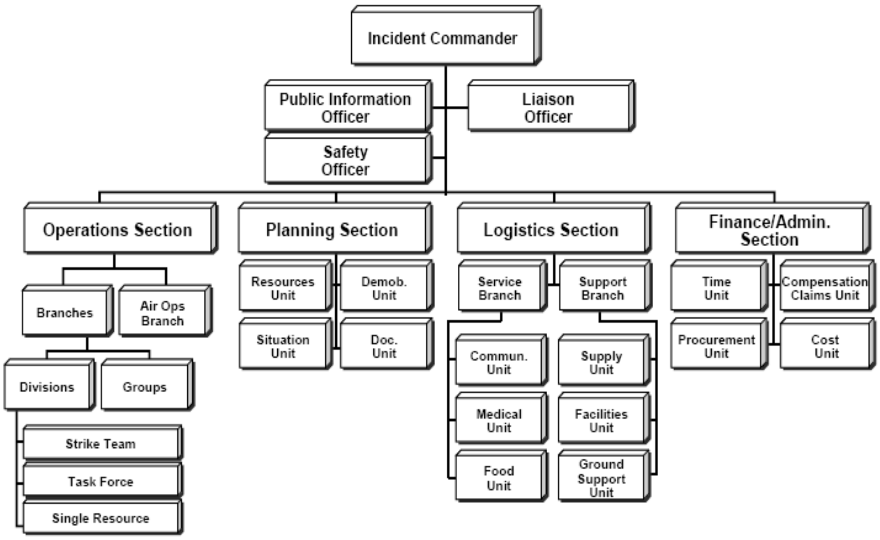


Figure 2. 6: ICS organizational structure (Source: FEMA, 2013)

The responsibilities and functions of the **ICS** system are further outlined in Table 2. 2 below.

Table 2. 2: A brief explanation of the various departments within the **ICS** system (FEMA, 2008).

Department/Section	**Purpose/Responsibilities**
Incident Commander	Responsible for overall incident management, including ensuring clear authority and knowledge of agency policy and managing planning meetings as required.
Public Information Officer	Responsible for providing timely information for use in press/media and arranging interviews/briefings
Safety Officer	Responsible for managing safety processes by reviewing the Incident Action Plan for safety implications and approving the Medical Plan
Liaison Officer	Responsible for liaising between two organizations to communicate and coordinate their activities by providing specific information and requirements

Operations Section	Responsible for managing all tactical operations at an incident
Planning Section:	Responsible for providing planning services for an incident and collects situation and resources' status information, evaluates it, and processes the information for use in developing action plans
Logistics Section	Responsible for providing transportation, communication, facilities, food and medical services.
Finance/Administration Section	Responsible for managing all financial aspects of an incident.

The ICS Planning Process

Since poor emergency management is often linked to inadequate planning, ICS uses a simple yet thorough process for planning which involves:

- Evaluating the situation.
- Developing objectives.
- Deciding on a strategy.
- Deciding on appropriate resources (FEMA, 2008).

During the initial stages of incident management, planners should develop a simple plan that can be communicated through concise verbal briefings. The plan, as mentioned here, refers to the documentation of statutory obligations for dealing with risks, the procedures for responses, the agencies required for the responses and the responsibilities of each stakeholder (Alexander, 2005). According to Alexander (2002), the minimum requirements for documenting planning arrangements for EM are based on effective risk assessment and on communication arrangements between agencies. While the contents of an emergency plan may vary based on the risks that the plan aims to manage (Dillon et al. 2009), the interactions between agencies are expected to be based on an effective evaluation of the situation. Under the ICS planning arrangements in the USA which is adaptable and scalable (Buck et al. 2006), it may be necessary for such a plan to be developed rapidly and without sufficient information. However, such plans require additional lead time, staff, information systems and technologies over time to enable more detailed planning. While including the implementation of formalized steps through a written Incident Action Plan (IAP) often help such plans, there are limitations in just developing a planning process for risk assessment on: evaluating the situation, developing objectives, deciding on a strategy and deciding on appropriate resources as listed above. The AIIMS system used in Australia seems to identify these limitations in the ICS planning process used in the USA by emphasising three key principles.

2.4.2 The Australian Inter-service Incident Management System (AIIMS)

The Australian Inter-service Incident Management System (AIIMS) is a system that allows effective and efficient management of domestic incidents (Council 2005). The framework allows for the integration of facilities, personnel, equipment, procedures and communications, all operating within a common organizational structure (Council, 2005).

AIIMS is based on three key principles:

- Management by objectives.
- Functional management.
- Span control (Council, 2005).

These key principles indicate the importance of setting objectives for the risk assessment process and also establish the key functional responsibilities and relevance of collaboration between multi-agency teams in the risk assessment process.

AIIMS' Organizational Structure

Used by all levels of government (national, state, agencies and local), AIIMS allows for organizational flexibility and is normally structured to facilitate activities in four functional areas: control, operations, planning and logistics. Figure 2.7 shows the functional structure.

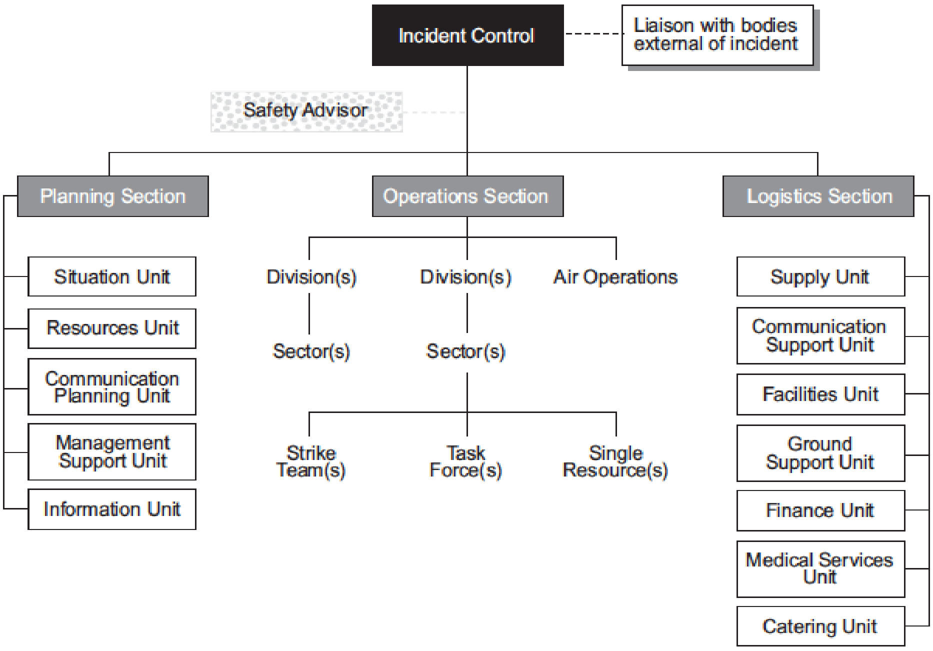


Figure 2.7: Functional structure of AIIMS (Source: The Australasian Inter-Service Management System, 2004)

The responsibilities and functions of the AIIMS system are further outlined in Table 2. 3 below.

Table 2. 3: A brief explanation of the various departments within AIIMS (Council, 2005).

Department/Section	**Function/Responsibility**
Incident Control	Oversees all activities necessary to manage the incident and distributes the functions to each organization.
Planning Section	Responsible for the collection and analysis of information and the development of plans for an incident.
Operations Section	Responsible for managing all tactical operations within an incident.
Logistics Section	Responsible for providing human and physical resources, facilities, services, and materials to support the management of an incident.

It can be noticed that each department and section have specific responsibilities and functions which they perform, all aimed at mitigating the impact of any disruptive event. However, the AIIMS organisational structure emphasises the importance of the flow of information between all departments and sections which are facilitated by different agencies.

Incident Action Planning and Communication

The Incident Management System is supported by the process of Incident Action Planning which is used to communicate throughout all levels of the structure to those involved in an incident, providing information and direction, and ensuring that all the section officers have the latest information on the current incident. A planning meeting brings together all members of the incident management team and produces an Incident Action Plan (IAP).

The importance of communication in effective incident management cannot be over-stressed. Briefings are a key element of this, ensuring a flow of information between all members of the incident management team. Three types of briefing are used: before the team arrives at the incident, upon arrival and at regular intervals during the incident, and providing briefing to sector and division commanders (Council, 2005). However, it can be noticed that the AIIMS structure focuses largely on the response phase when it is often too late to assess risks with respect to prevention since the event is already occurring. Regardless, the focus on three types of briefings in the AIIMS structure emphasises the role and importance of interaction for dealing with the ongoing risks of an event that is happening. It also emphasises the relevance of this research to all phases of EM and to the six steps of IEM as seen in the UK model.

2.4.3 UK Organizational Structure for Disaster

Although the Australian and American structures give a useful context, the UK's organisational structure is the main structure utilised in this research, given that it focuses on the UK. While LRFs is one of the main methods for multi-agency collaboration in England, a number of other organizations and policy initiatives also relate to multi-agency collaboration. One such policy is the Joint Emergency Services Interoperability Programme (JESIP) and the one such organization is the DCLG (Pollock et al., 2013). While the DCLG links directly to LRFs, JESIP is a policy that runs in parallel in order to enhance the collaboration between three Category 1 responders, namely the fire and rescue, police and ambulance services (Cabinet Office, 2013; Pollock et al., 2013).

2.4.3.1 Joint Emergency Services Interoperability Programme (JESIP)

The Joint Emergency Services Interoperability Programme (JESIP) was explicitly created to improve the collaboration between the UK's three 'blue light' responders (the police, fire and rescue, and the ambulance service). It aims to enhance interoperability by fostering a "shared ethos, reducing bureaucracy and improving situational awareness" (Pollock et al., 2013). The programme focuses on reworking and training, testing and exercising and procurement and equipment activities. JESIP was established following recommendations put forward after investigations had been made into a series of man-made and natural incidents such as the 2010 shootings in Cumbria, the Hillsborough football disaster, the 2005 London bombings and the 2007 flooding (Rubin et al., 2005; Pitt, 2008; Chesterton, 2011). A common theme in the enquiries into these disasters was the need for greater cooperation and interaction between emergency responders. It was felt that increasing collaboration would ultimately reduce loss of life (Ellwood and Philip, 2013). A temporary programme lasting two years, JESIP entails emergency services training together rather than in isolation, sharing information and working from a common emergency procedure. It, therefore, has been argued that, as a result, JESIP will have a lasting positive impact on responders' interoperability (Pollock et al. and JESIP, 2013). However, this two years' programme has no formal or informal platform that enhances collaboration, cooperation and interaction between multi-agencies especially between Category 1 responders, thus emphasising the importance of this research aim.

JESIP calls for the police, fire and ambulance services to collaborate on risk assessment and information sharing. Although JESIP's main tasks can be divided into the four main features of doctrine and organization, shared situational awareness, operational communication and training and exercising, there is no evidence of an interactive model, platform or support that enhances multi-agency team collaboration in the risk assessment process. For example, in terms of doctrine and organization, JESIP calls for the three blue light responders to commit to interoperability in their doctrines and to include it in training manuals (Ellwood and Philip, 2013). In addition, JESIP involves an assessment system of the extent of responders' interoperability and the creation of Joint Operating Principles for interoperability. However, there is no enhancement modality to enhance the assessment system. One of the programme's tasks was to set up a governing organization that covers all three blue light responders so as to ensure their future interoperability (Ellwood and Philip, 2013). Moreover, JESIP aimed at defining a strategy to encourage the recording and sharing of lessons learnt in past emergencies, but there is no stated support system for sharing such lessons among agencies.

In terms of communication, JESIP includes a revision of how responders communicate using shared radio technology and on the use of common terminology when responders work together (Pollock et al., 2013). But this factor is often used during incident response and during joint exercises and is not part of a continuous risk assessment process as emphasised in Cabinet Office (2013). JESIP aims to improve shared situational awareness through the development of a number of shared models and frameworks, but unfortunately, it is mostly used during the response phase without collaborative use during the four steps before the response phase. While JESIP allows for the creation of guidelines for sharing information between responders, it is yet to be maximised for the pre-incident phases and steps in the UK. Finally, JESIP involves the development of numerous training courses and packages at different levels of emergency response. JESIP calls for the use of common terminology within these training courses which will be useful for multi-agency response (Pollock and JESIP, 2013). However, it is equally important that collaborative interaction between agencies is enhanced prior to the response phase in order to make multi-agency responses more effective.

The overall aim of JESIP is to save as many lives as possible by ensuring that responders work together effectively and efficiently when they need to. This involved creating a shared set of principles that can be applied to all major events that require the services to collaborate. Moreover, JESIP aims to make sure that incident plans are put into action quickly and can be communicated across different agencies. While the outcomes from JESIP will affect the performance of agencies that operate within LRFs, it is also possible for the JESIP outcomes to be improved and for multi-agency collaboration to be enhanced through an interactive map such as the one proposed in this research. The next section examines another department that is directly linked to the LRFs, the Department of Communities and Local Government.

2.4.3.2 Department for Communities and Local Government (DCLG)

As previously explained, in the Civil Contingencies Act of 2004 the UK's central government gave local governments a set of responsibilities for emergency preparedness, response and recovery. This created the need for a connection between these two levels of government relating to emergency management. In this respect, the Department for

Communities and Local Government (DCLG) is the central governmental department responsible for liaising with local governments. The DCLG is responsible for supporting LRFs with information that could be useful in preparing and in planning for major emergencies, in risk assessment and in responding to disasters (Achour et al., 2015). The DCLG works closely with other central government departments as well as local authorities and the previously mentioned LRFs (Cabinet Office, 2013).

Within the DCLG, the Resilience and Emergency Division (RED) interacts directly with the LRFs with the goal of providing support for collaboration and co-operation in risk assessment and in planning for different types of hazards (Peer Review, United Kingdom, 2013). RED's structure involves each LRF having an individual Resilience Advisor to foster a strong working relationship between the central and local authorities. By having an advisor, each LRF has a point of contact with the DCLG who supports them with data and advice about planning, risk assessment, preparation and response (Peer Review, United Kingdom, 2013). Resilience Advisors pass on information from central government, encourage the sharing of information between responders and LRFs, promote good practice and participate in risk assessment, training and exercises (Cabinet Office, 2013). By having a small group of advisors, one for each LRF, it is hoped that the collaboration between different LRFs can also be improved which will, in turn, improve the overall response to wide scale national emergencies. In addition, the DCLG RED actively supports preparedness and risk assessment by helping LRFs meet national planning requirements through the provision of data, information and policies from central government that are relevant to different kinds of hazards (Department for Communities and Local Government, 2012).

During an emergency, DCLG has a set of procedures designed to support the local response (Peer Review, United Kingdom, 2013). Some of these activities are to oversee local activities such as ensuring the creation and effective operation of SCGs. Moreover, the DCLG ensures that accurate, up- to-date information about a situation is created and maintained. Depending on the size of the event, this can relate to one local area or a number of different areas. It is the DCLG's role to establish and maintain communication and update information between the responders and the central government, including up to the Cabinet Office. The Department may create a central hub for the collection and communication of information that can act as a point of contact between local responders and the multi-agency co-ordination groups. Furthermore, the DCLG is closely involved connecting different LRFs for mutual aid and for the exchange of information about events taking place. The Department is also responsible for helping responders give coordinated and clear public information. Finally, the DCLG has responsibility for overseeing the fluent, efficient transition from response groups to recovery groups (Department for Communities and Local Government, 2012).

In short, the Department for Communities and Local Government is the branch of the UK's central government which is connected to local government and, therefore, to Local Resilience Forums. The DCLG has a specialized resilience team to support LRFs in their risk assessment, preparedness for, and response to, emergencies. It links to them directly by sharing and exchanging information in preparation for emergencies and supports the communication of the requirements that will help create local planning and policies to deal with such emergencies.

To summarise, JESIP and the DCLG represent important elements within multi-agency collaboration in England. While JESIP is a policy that aims to improve the collaboration between the police, fire and rescue and ambulance services, the DCLG provides LRFs with information to help and guide their risk assessment and their preparedness for dealing with hazards. Both support multi-agency collaboration and risk assessment in their own way.

2.4.3.3 Local Resilience Forums' (LRFs) Composition

Local Resilience Forums (LRFs) are multi-agency partnerships made up of representatives from local public services including the emergency services, local authorities, the NHS, the Environment Agency and others. These agencies are known as Category 1 Responders as defined by the Civil Contingencies Act. LRFs are supported by organisations known as Category 2 responders, such as the Highways Agency and public utility companies. They have a responsibility to co-operate with Category 1 organisations and to share relevant information with the LRFs. The geographical areas that the forums cover is based on police areas (Anderson and Adey, 2012).

There are currently 8 groups of regions in England as shown in Figure 2.8. These are North West, North East, Yorkshire and Humber, West Midlands, East Midlands, East of England, South West and South East regions. These regions are divided into a further 38 areas (see Figure 3.8 below). Most of these are counties, although some are metropolitan boroughs. Similarly, some of the areas are metropolitan such as Greater Manchester while others are predominantly rural such as Cumbria. Each of these has an LRF. These

38 LRFs serve communities within the boundaries of the police areas across England, as shown in Figure 2. 8. The subjects of this research are the Local Resilience Forums (LRFs) in England. This research will explore and investigate the Greater Manchester LRF, one of the 38 English LRFs.

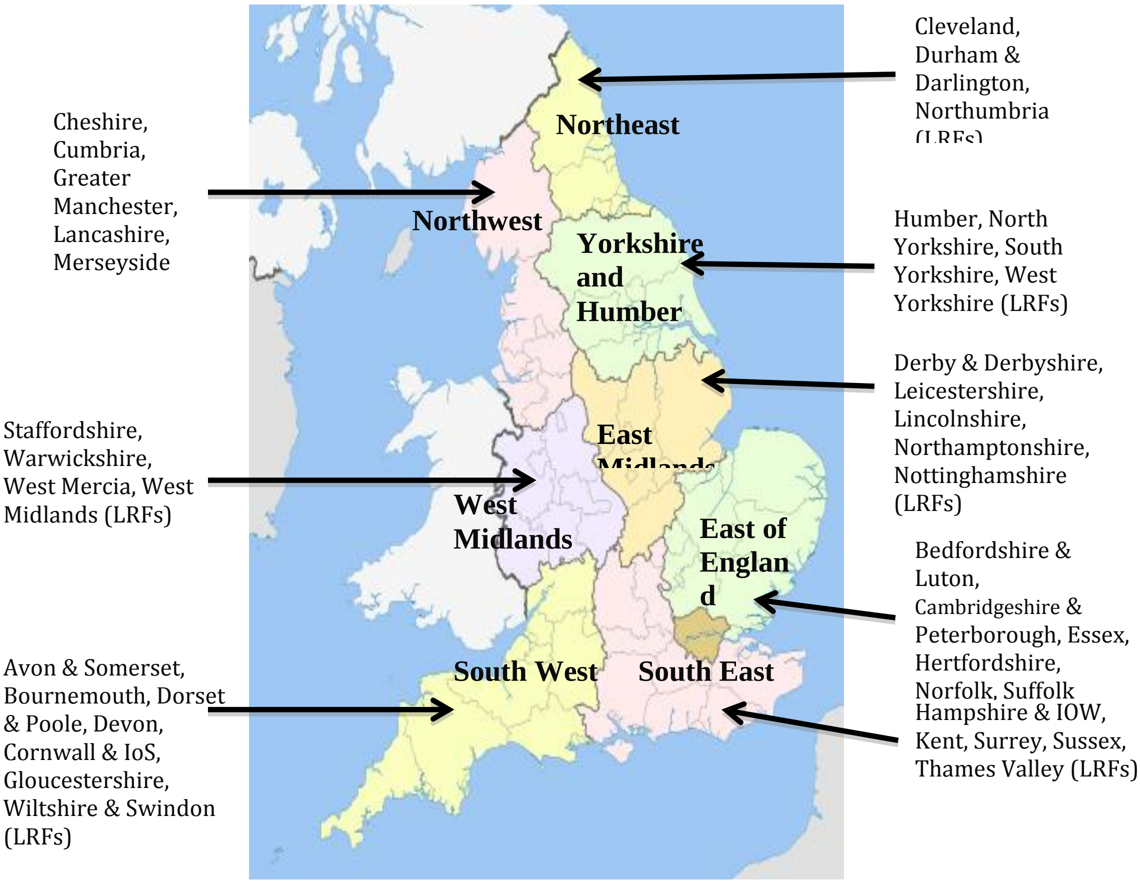


Figure 2. 8: England's 38 Local Resilience Forums (LRFs)

In summary, Local Resilience Forums cover the whole of England. Each region has a number of LRFs and there are 38 in total. LRFs are partnerships between category 1 responders and are supported by category 2 responders. The responsibility of each LRF is to facilitate collaboration between all emergency responders in a given area in preparation for, and response to, emergencies. This research will focus on the Greater Manchester LRF.

2.4.3.4 Local Resilience Forums' (LRFs) Role

The national emergency management framework in the UK distinguishes between the single agency management's and the multi-agency management's response to, and recovery from, emergencies. Their roles and responsibilities and the interaction between them and between individual agencies are described in the statutory guidance accompanying the 2004 Civil Contingencies Act (Cabinet Office, 2012). Distinction is also made between the single agency command and control structure (often termed Gold, Silver and Bronze) and multi-agency coordination (operating at three levels: strategic, tactical and operational). The following section will outline in detail the national, and then the local, levels of emergency management in the UK. It explains the connection between central government and Local Resilience Forums in England which are the main mechanism for multi-agency collaboration at the local level (Anderson and Adey, 2012).

At the level of central government, the Civil Contingencies Secretariat (CCS) has been a key player in emergency management in the UK since its creation in 2001. It supported the passing of the 2004 Civil Contingencies Act. The CCS was formed in response to a series of incidents in 2000/2001 such as severe flooding, the fuel crisis and the Foot and Mouth outbreak of 2001. These events showed weaknesses in the emergency management systems in the UK (Cabinet Office, 2004). The CCS has a number of responsibilities including implementing the Civil Contingencies Act, directing the National Risk Assessment and coordinating the activities of central government in times of emergency. Moreover, the CCS organises collaboration between the public, private and voluntary sectors and advises Local Resilience Forums (Secretariat, Civil Contingencies Act, 2004).

Local Resilience Forums are the primary vehicle for multi-agency partnerships in emergency management. Their role is to identify possible risks, undertake planning, preparation, maintenance, response and recovery and also the prevention of extreme events. They consist of delegates from local public services, including the police, fire and ambulance services, the National Health Service, (NHS), local authorities and other Category 1 responders as identified in the Civil Contingencies Act (Sircar et al., 2013). Category 2 responders support the work of LRFs. Such Category 2 responders include the Highways Agency, transport operators in England and utilities companies. These groups are legally obliged to collaborate and share information with the LRF. There are a total of 42 LRFs in England and Wales, of which 38 are in England (Cabinet Office, 2013a).

The Resilience and Emergencies Division (RED) is a key partner for the CCS and for LRFs. RED is part of the Department of Communities and Local Government (DCLG). The DCLG connects central and local government in England. RED has partnerships with

LRFs, the CCS and other central government departments to enhance the preparedness for emergencies that go beyond the capacity of a single LRF. The RED is used to ensure that national policies are followed by LRFs. This is achieved by the distribution of information to, and between, the 38 LRFs in England. For instance, RED arranges an LRF conference every two years which is co-chaired by the DCLG and the CCS. These conferences give representatives from each of the English regions a chance to share and discuss information.

The concern of this research is with the strategic level of the multi-agency coordination in Local Resilience Forums. In the UK, this is broken down into a counties and metropolitan approach. As a result, this research will focus on the strategic role and function of Local Resilience Forums (LRFs) which are the principal mechanism for multi-agency cooperation as defined under the Civil Contingencies Act (CCA) (Cabinet Office, 2013a). They will be described in more detail later in this chapter.

The role of Category 1 & Category 2 responders within this framework will be investigated in more detail in this research. Other partners such as the military and voluntary sectors also provide a valuable contribution to LRF work (Adey and Anderson, 2012).

The LRFs' work is to identify potential risks and produce emergency plans to either prevent or mitigate the impact of any incident locally (Cabinet Office, 2013a). A Local Resilience Forum (LRF) is not a legal entity. However, the CCA and which regulations The CCA's regulations If yes, change 'the regulations' to 'their regulations' indicate that responders have a collective responsibility to plan, prepare and communicate in a multi-agency environment within the Forum. The representatives from category 1 responders must attend the meetings of the Forum which are held once every six months. In short, this research will study the LRFs in England because they constitute the main method of multi-agency response within the UK (Cabinet Office, 2013b). This study will investigate the collaboration, through LRFs, between Category 1 & Category 2 responders in this county. More details on LRFs are outlined below.

The fundamental purpose of the LRFs in England and Wales is mainly strategic in that it acts as a coordinating group for local responders involved in preparedness for emergencies at the police force area level. Therefore, it provides a local Forum for local issues, thus supporting the duty holders, category 1 and category 2 responders in performing their legal responsibilities more effectively than they would if they were acting on their own. The Forum enables them to bring issues forward for discussion and agreement on a combination of initiatives and to co-ordinate responses to government initiatives (Cabinet Office, 2013b).

The LRFs also help to coordinate risk assessment through the production of the Community Risk Register (CRR). The preparation of the CRR is important in the sense that it enables the LRF members to establish a consistent understanding of the hazards and threats within the LRF area. The risk assessment also helps determine the priority issues with which the coordinating agencies must be ready to deal.

The LRF does not have an operational role. When an emergency occurs and at least one of the Category 1 responders declares a major incident, it only helps determine a procedure for the formation of a Strategic Co-ordinating Group (SCG) usually, though not always, led by the police. It is then the task of the SCG to co-ordinate the response to the emergency and it is also likely to take a role in the initial stages of recovery. Afterwards, if required, it is replaced by a Recovery Co-ordinating Group (RCG). While the SCG operates the LRF continues to meet (Anderson and Adey, 2012).

Strategic Co-ordinating Group (SCG)

Many agencies are involved in responding to disaster. This requires co-operation and the provision of support to one another. The procedures undertaken, and the capabilities held, by these agencies have to be successfully integrated in order to respond and recover effectively.

A national framework has been developed that can be applied to emergencies of any size and nature. It is a general framework with the flexibility to be adapted to the requirements of specific situations. The use of this framework, agreed upon by all agencies, will assist in the collaboration between agencies in different geographical locations and make sure that each agency has a clearly defined and understood role and responsibility in response to an incident.

It is crucial to separate the different functions of single agencies and multi-agency groups. While single agencies have control over their own staff and equipment, multi-agency groups are organized to bring together, and co-ordinate, the activities of these agencies. Moreover, they define the strategy and the common objectives for the entire multi-agency response. The terminology between single agencies and multi-agency groups also differs.

Single agencies use “Gold” and “Silver” to refer to different levels of command. In contrast, multi-agency groups have a Strategic Co-ordinating Group (SCG) and a Tactical Co-ordination Group (TCG) (Cabinet Office, 2013b). It is important that different terms are used to avoid confusion between agencies. The different roles of individuals can add to this confusion; for example, the Gold Commander in a single agency (such as the police) might act as the Chair of the SCG. This might lead some people to refer to them as the “Gold Commander” within the SCG. However, this is misleading because their role in the SCG is fundamentally different. Overall, the top level in a single agency will have a command function whereas the top level in the multi-agency group will have a co-ordination function (Cabinet Office, 2013b).

Planning at the strategic level is intended to take into account the wider context of an emergency. This is achieved by defining and communicating the overall strategy and objectives for the emergency responders, as well creating the policies and frameworks that will be used by the lower level responders. At the strategic level, the long-term risks and impacts are determined and the overall progress of a response is monitored. While the single agencies planning at the strategic level, sometimes it is necessary for different agencies to collaborate. This is required when an event has a significant impact, involves the use of substantial resources, involves many different organizations and/or takes place over an extended period of time. In these circumstances, the multi-agency SCG group will be formed.

The SCG will be located at a safe distance from the site of the emergency. This location is referred to as the Strategic Co-ordination Centre. The SCG is often, but not always, chaired by the police. The police will co-ordinate other organizations if there is an immediate threat to human life or public order. However, in other kinds of emergency the chair of the SCG may be from another agency (such as a public health agency) that may chair the group in a human health emergency (Anderson and Adey, 2012). Planning and response at the strategic level in England is the responsibility of Local Resilience Forums (LRFs). LRFs bring together local responders and private businesses. Through LRFs the procedure for establishing SCGs is created, in order to co-ordinate the multi-agency response in the event of an emergency.

The function of the SCG is to be ultimately responsible for multi-agency co-ordination and to create and communicate the policies and the strategic framework to the lower level groups will follow. The SCG outlines the priorities of the lower level responders and takes care of communication with the media and the public. It also plans operations in the recovery phase of an emergency. The SCG is able to create specialized supporting groups for particular tasks; for instance, while the SCG focuses on the immediate response to an emergency, they can establish a Recovery Co-ordinating Group (RCG) to co-ordinate the longer-term recovery.

Recovery Co-ordinating Group (RCG)

The RCG works alongside the SCG, supporting the SCG's activities and ensuring that they do not compromise the medium to longer-term recovery. The collaboration between the two groups is often aided by having them in the same location. The RCG is a multi-agency group working in the recovery stage. It is given the task of creating the recovery strategy. This involves an assessment of the impact of a disaster, the identification of possible longer-term economic regeneration as part of the recovery and the early identification of any opportunities to strengthen the resilience of the community in the future.

The RCG is founded on a number of principles relating to recovery from a disaster. It seeks to support the community to recover by beginning the process as soon as possible, working closely with the SCG until eventually it replaces the SCG. It provides specialist services, information and resources. It is a collaborative endeavour which aims to be accepted and understood by all responders and to include active participation from the affected community, including the private sector. It aims to prioritise human welfare. Most importantly, it aims for a comprehensive, integrated framework for guiding recovery efforts that is flexible enough to deal with the needs of different communities. The group meets on a daily, and then a weekly, basis until there is no longer a need for multi-agency co-ordination in the recovery stage. The group then stands down.

To summarise, an LRF establishes a Strategic Co-ordination Group when there is a need for multi-agency collaboration to respond to an emergency. As soon as possible, an SCG will create a Recovery Co-ordination Group to focus on the recovery phase. While the SCG concentrates on the immediate response, the RCG focuses on recovery, with the two groups communicating when required. When the SCG stands down, the RCG takes over until there is no longer a need for multi-agency collaboration in the recovery effort.

To conclude, a number of groups are involved in the UK's emergency planning and response. At the level of central government, the CCS created the Civil Contingencies

Act in 2001. The act outlines the requirements of all local authorities in the UK. In England, this has led to the creation of LRFs in order to enhance the collaboration of multiple agencies at the strategic level. LRFs co-ordinate and ensure collaboration between local responders in preparing for emergencies. This activity is supported by the central government through the Department for Communities and Local Government. This department has a specific unit, called the RED, which interacts directly with LRFs and has the goal of providing information and advice. Figure 2.9 shows a flow chart of this system. This study is concerned with multi-agency collaboration in the preparedness stage, focusing on risk assessment within emergency management. Therefore, it will focus on LRFs in England. LRFs are worthy of investigation because they are the principle method of multi-agency collaboration for preparedness at the strategic level. This research focuses on Greater Manchester Local Resilience Forum in England, one of the 38 LRFs in England. The research will investigate how these LRFs work and, ultimately, evaluate how Category 1 & Category 2 responders collaborate in preparing for disasters.

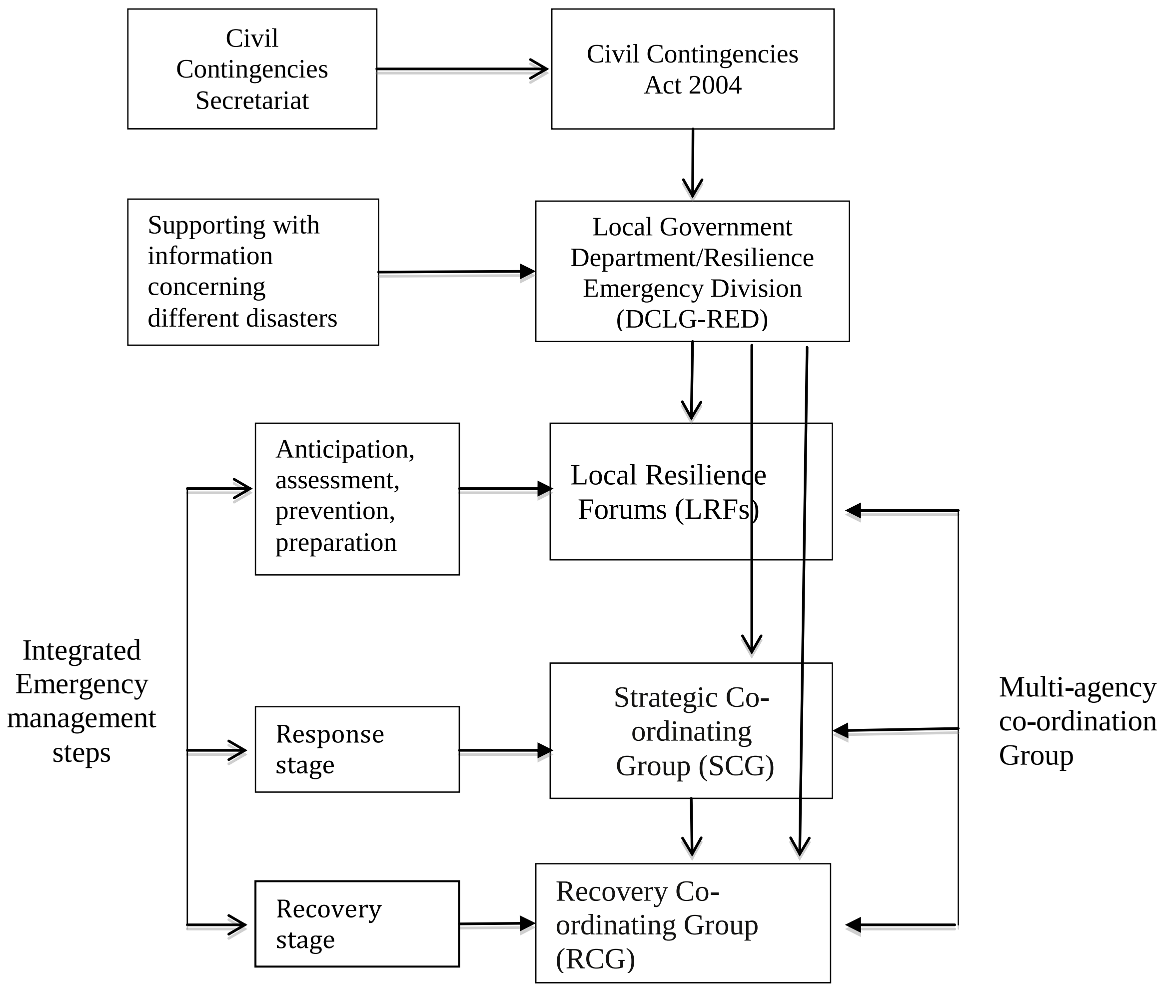


Figure 2. 9: Flow chart of the system used in England & Wales for emergency planning and response (Secretariat, Civil Contingencies Act, 2004).

Figure 2. 9 and this entire section indicate the steps in IEM requiring interaction between the anticipation, assessment, prevention and preparation, response and recovery stages. The Local Government Department/Resilience Emergency Division (DCLG-RED) inform different forums, groups and departments in the UK which are facilitated by different stakeholders and maintained by multi-agency coordination group. The network of interaction illustrated in Figure 2.9 and the nature of communication required for risk assessment to be effective function through collaboration and thus require an enhancement mechanism or model such as the one proposed in this research. Section 2.4.4 on stakeholders further helps to justify the importance and relevance of an interactive map which can assist in enhancing multi-agency team collaboration in the risk assessment process. By examining all the stakeholders involved in EM and their various, but complementary, responsibilities and roles, the importance of an interactive map will be clear as it will minimise confusion and enhance collaborative working.

2.4.4 Stakeholders

This section outlines the roles and responsibilities of the main agencies and sectors that are likely to become engaged in disaster management at a local level. Stakeholders are people who have, or think they have, a personal interest in the outcome of a policy. This interest motivates them to attempt to influence the development of that policy. This section explains arrangements in England and includes information on:

- Police services;
- Fire and rescue services;
- Health bodies;
- HM Coroners;
- Local authorities;
- Government agencies and other non-departmental public bodies (NDPBs);
- The Armed Forces;
- The private sector;
- The voluntary sector, and
- The community.

The Civil Contingency Act (CCA) divides responders into two categories and puts a different set of duties on each of them (Cabinet Office, 2010).

Category 1 Responders:

Police services: The police generally co-ordinate the activities of the other responders, whilst ensuring that the scene is preserved and evidence safeguarded – particularly where terrorism is suspected. They arrange for any victims to be removed from the area, acting on behalf of HM Coroners in the case of deaths, and, if necessary, coordinate search activities.

Fire and rescue services: The main role of the fire and rescue services in an emergency is the rescue of citizens trapped by fire or wreckage. They are also responsible for extinguishing fires and taking protective measures to prevent the fire from spreading. Moreover, they assist other agencies, such as the ambulance service and the police, in the removal of bodies and, where exposure to chemicals is involved, decontamination.

Ambulance services: As part of the National Health Service (NHS) the ambulance service is responsible for on-site response to short or sudden emergencies, as well as taking the victims to different hospitals, depending on priority and the types and numbers of the injured.

Acute Trusts and Foundation Trusts: Acute Trusts and Foundation Trusts manage hospitals in England. The ambulance service will designate the hospitals that will receive casualties in the event of a major emergency.

Primary and community care services: These cover a range of health professionals who would be involved in the recovery phase of an emergency. This category includes general practitioners, pharmacists and mental health services, amongst others.

Primary Care Trusts: Primary Care Trusts (PCTs) in England are responsible for commissioning health care services locally and cooperate with the Health Protection Agency (HPA).

The Health Protection Agency (HPA): This is a non-departmental public body which identifies health hazards caused by infectious disease, hazardous chemicals, poisons or radiation by using surveillance activities such as horizon scanning, risk assessment and modelling. It provides public health advice to government departments, to the NHS and to the general public.

Port health authorities: Operating at seaports and airports, port health authorities' main duties in an emergency are to control infectious disease. They are also responsible for environmental protection, imported food control and hygiene on vessels.

Maritime and Coastguard Agency (MCA): The MCA is an agency of the Department for Transport. The main responsibility of HM Coastguard is the initiation and co-ordination of maritime search and rescue, whether at sea or on the coastline/shore. Furthermore, HM Coastguard can assist other emergency and local authorities during civil emergencies.

Local Authorities (LAs): The local authority structure in England consists of two tiers: single tier and two tier. In the latter, a county council and several district councils divide responsibilities for local authority services. County councils are responsible for children's social services, whereas district councils are responsible for leisure, environmental health, housing and planning control, among others. In the single-tier system, one authority is responsible for all local authority functions. Local authorities collaborate with a range of bodies to support emergency services during emergency response and recovery from disaster. Their services may include the provision of shelters, medical support and long-term survivor welfare.

Environment Agency (EA): The aim of the EA is to protect and improve the environment in England and Wales. The EA deals with many different types of incidents affecting the natural environment and human health or property. This may include issuing flood warnings, the prevention/control of pollution, and investigating causes of an incident. It also plays a significant regulatory/advice role.

Category 2 Responders:

Utilities, telecommunications and transport providers: These private sector organizations, although not regularly involved in emergency response and recovery, do play an important role (Cabinet Office, 2010). They include:

- Gas and electricity transmitters and distributors
- Fixed and mobile telecommunications' providers
- Water and sewerage services, and
- A range of transport companies.

The Highways Agency: As an agency for the Department for Transport, the Highways Agency is responsible for, amongst other matters, managing traffic, providing information to road users, improving safety and tackling road traffic. Many of its functions are relevant to emergency response.

Strategic Health Authorities (SHAs) in England: As the local headquarters of the NHS, SHAs are responsible for coordinating the health response where an incident is widespread and affects several hospitals.

The Health and Safety Executive (HSE): The HSE's responsibility is to protect people's health and safety in the workplace by ensuring control of risks. Its remit includes the health and safety of other responding agencies. This may include pollution clean-ups, inspection of dangerous structures, provision of emergency mortuaries, and providing for the welfare of response personnel (Cabinet Office, 2010).

2.4.5 Summary

To summarise, disaster management and risk assessment is organised in different ways in the USA, Australia and the UK. The UK's structure is based on LRFs which are regional organisations that are composed of Category 1 and Category 2 responders. These stakeholders have their own roles and responsibilities within the LRFs.

2.5 Analysis of a Disaster Response Exercise

In order to understand how UK organisations test their preparedness for disaster the outcome of an exercise conducted by the LRF in Staffordshire is presented here. Although it does not cover the practices worldwide, this analysis has enabled the researcher to identify typical challenges faced by agencies when trying to collaborate in responding to disasters. This case study was conducted by the LRF in Staffordshire and can be classified as an LRF primary example. However, it provides secondary data for this research since the researcher uses this case study of a LRF simulation exercise in Staffordshire to further justify the importance of the set of objectives outlined for this research.

One way that LRFs can test their preparedness is by exercises which simulate incidents (Staffordshire Prepared, 2013). These simulations highlight the strengths and weaknesses of emergency plans and the processes through which multiple agencies collaborate. Exercise TRITON was conducted by the LRF in Staffordshire to explore how a particular LRF was prepared for multi-agency response to disaster (Staffordshire Prepared, 2013). As such, it provides a relevant and useful case study. Exercise TRITON took place over a five-day period in June 2013. It was the largest exercise of its kind undertaken by the LRF in Staffordshire which aims to organize multi-agency exercises every three years. The exercise was based around a simulation of an event affecting Blithfield Reservoir, operated by South Staffordshire Water. The exercise simulated the effects of a dam failure with the aim of practicing “a multi-agency response to a catastrophic dam failure”. The specific objectives of the simulation included the testing of preparedness for disaster and the multi-agency “command and control arrangements”. In other words, TRITON was a case study for multi-agency collaboration in response to a disaster (Staffordshire Prepared, 2013).

The outcomes from this case study highlighted the gaps and weaknesses in some aspects of multi-agency collaboration in terms of technology, organizational structure and process.

Technology

Communication technology, including radio, Internet and telephone technology, was a source of problems during the exercise. For instance, problems were reported with radio communications. At the police HQ the signal for the airwave radio channel was weak and some responders were reported to be using different radio channels. Moreover, the wireless Internet signal provided at the Fire Station that was utilised was intermittent and was not operational at all for four hours. Furthermore, there was a difference between the use of the Internet by the police and by the fire service. While the police HQ had a generic wireless account that could be used by all users, the Fire Station employed a system where each organization had to set up their own individual account. This caused a delay in responders accessing the Internet. Telephone communications between the Strategic Coordination Group (SCG) and the Tactical Coordination group (TCG) also proved to be problematic. Although teleconferencing equipment was provided across the agencies, users experienced difficulties in hearing because some equipment did not come with adequate microphones. In addition, although High Integrity Telecommunications (HITS) was available to TCG, a number of the responders did not know what the system was or how to use it. A majority of them, therefore, did not use the system at all (Staffordshire Prepared, 2013).

Aside from communication, mapping was also a crucial technological problem during the exercise. Firstly, neither SCG nor TCG used a Geographical Information System (GIS) for mapping. GIS is an effective tool, helping responders to access up-to-date information and real time observations quickly. Despite the advantages of GIS, paper maps, which took time to be fully understood, were used. When the use of GIS mapping was requested by SCG, it was not implemented by TCG. Evaluators suggested that this was due to a lack of knowledge of GIS and recommended that training workshops be held to remedy this. Secondly, at the planning stage of the exercise, workers at Staffordshire County Council could not utilise the GIS maps that were available on the National Resilience Extranet because they had to be manipulated before they could be viewed properly. In an emergency this would cause costly delays.

Overall, multi-agency collaboration during this exercise was hindered by a range of technical problems with the communication and the information sharing technology being used. However, the exercise also demonstrated a series of more general issues relating to how the multi-agency response was organized.

Organizational structure

In the evaluation of the exercise, it was highlighted that the chairperson of the TCG was present, by telephone, in all of the SCG meetings. These four meetings, which lasted up to almost two hours, took the TCG chairperson away from dealing with TCG activities.

Additional problems with the TCG were also noted. Some participants felt that each agency should send more than one representative to attend the TCG meetings, while others criticized the fact that the chair of the TCG also represented the fire and rescue service. It was suggested that the chair should have a single responsibility rather than two.

The report reviewing the exercise generally called for a greater emphasis on multi-agency collaboration and a higher level of communication between the two main groups, namely SCG and TCG. The problems concerning collaboration were most evident, however, when the processes underlying the emergency response were investigated (Staffordshire Prepared, 2013).

Planning and Process Problems

TRITON was intended to test a collection of emergency plans, but some of these plans were discussed and used more than others. Many respondents reported that, for example, the 'Reservoir Plan' was not used at all. This suggests that responders lacked knowledge of, or access to, all the emergency plans that had been drawn up. This perhaps relates to a lack of interaction and collaboration between the different planning and response groups. Without comprehensive, shared access to relevant information to prepare for an event, the responders could not utilize certain plans once the event was taking place.

A lack of collaboration between the strategic and tactical levels was evident. Before and during the event, communication between the main two groups, SCG and TCG, was very weak. The two groups worked independently of each other, without any strong co-ordination to exchange information and to understand each other's actions. The evaluation of the exercise called for a "Single Point of contact for communications between SCG/TCG" (Staffordshire Prepared, 2013).

This lack of co-ordination went beyond the two main multi-agency groups; two agencies, namely the City Council and the Animal Health and Veterinary Laboratories' Agency (AHVLA), should have been involved in the preparation for such an incident. However, they were not and, furthermore, they were not contacted when they should have been during the event. This highlights the need for better and clearer co-ordination between different agencies before an event, to improve responses during an event. This point is further stressed by the fact that some Category 2 responders reported misunderstandings of the some of the terminology that was being used by the other agencies (Staffordshire Prepared, 2013).

Moreover, there was a misunderstanding between the multi-agency co-ordination groups and the individual response groups. The individual response groups did not fully understand the overall concept of the multi-agency groups' SCG and TCG. It was reported that many within the individual response groups were unclear about who their counterparts were in the multi-agency structure. The points to a need for all responders to have a clear understanding of the organizational structure and the responsibilities and roles of each group and, in addition, it points to the importance of good interaction between workers in different groups. This needs to happen in the preparation stage to avoid confusion during an incident (Staffordshire Prepared, 2013).

Consistent updates and reporting proved to be a problem in the exercise. The Situation Reports used by the responders in TRITON lacked consistency between the groups. In the preparation stage, template Situation Reports should be created and made fully available for use during an event. In TRITON, participants reported not knowing where to access such a template which led to a lack of standardization in these reports. This could have been avoided with better collaboration before the event. Clarity and the communication of information was a general problem. The report noted "information still ended up in the wrong hands where people did not understand why they were receiving…messages/emails". This shows the importance of clear lines of communication and the successful exchange of information between participants (Staffordshire Prepared, 2013).

Overall, the exercise demonstrated that while individual groups and agencies may undertake their jobs effectively, a lack of communication and organizational co-ordination between groups can hinder their overall response. In the conclusion to the report, the organisation at the centre of the LRF made a recommendation. This organization is the Staffordshire Civil Contingencies Unit (CCU) which was established to ensure that the region meets its legal requirements outlined in the 2004 Civil Contingencies Act. All category 1 responders in the region jointly fund the group and its role is to promote multi-agency collaboration including the sharing of "resources, capabilities and knowledge" (Staffordshire Prepared, 2013) across the different agencies. After evaluating the outcome of the TRITON exercise, it was recommended that the CCU look into using an IT system that allows for the sharing of information in real time between all agencies and groups. This system, it was suggested, should bring together all the information and procedures held by the different groups, allowing users to view and access information at different "layers", enabling users to switch between operational/tactical information and strategic level information. Although this recommendation relates to the sharing of information during an emergency, the only viable way to achieve such a collaboration platform would be to develop it and ensure users were trained in it during the preparedness stage. It would have to be part of the overall preparedness strategy to be effective in an emergency.

2.6 Challenges to Multi-agency Collaboration

Emergency management calls for the completion of dynamic, ever-changing tasks (Mendonça et al., 2007 and Salas et al., 2008). It has been suggested that the scale of disasters in recent years has made it important to move away from traditional, centralized disaster management activities (Aldunate et al., 2005; Bier, 2006; Perrow, 1984). In light of this fact, collaboration between multiple agencies is now seen as vital in disaster management (Waugh & Streib, 2006; Eide et al., 2012). Collaboration is simply when representatives of difference organizations combine their efforts, resources and knowledge to make decisions and produce things for which they share responsibility (Kamensky et al., 2004). While the necessity for collaboration has been established, the challenges relating to it are considerable. A lack of effective collaboration between different agencies is commonly cited in reports in disasters (see, for example, Norges Offentlige Utredninger, 2012).

Kapucu and Garayev (2011) suggested that weaknesses in multi-agency collaboration have led to numerous recent failures in emergency management. In the USA, Hurricane Katrina was an event in which collaboration between agencies was problematic, particularly between governmental agencies under the leadership of FEMA (Kapucu and Van Wart, 2006). In the case of 9/11, collaboration between intelligence agencies before the event was characterised by confusion and uncertainty, while in the case of Hurricane Katrina there was a lack of coordination between responders after the event. In both cases, limitations in interaction between agencies was cited as the reason for failures in response to these events and it is suggested that an increased focus on collaboration, interaction and a better understanding between agencies and stakeholders are required (Kapucu & Van Wart, 2006).

One of the challenges associated with collaboration is that it requires several layers of interaction between the managers and leaders of different agencies and stakeholders

(Kapucu and Garayev, 2011). This suggests that effective collaboration requires that issues concerning communication within, and between, response organizations are addressed. These issues can relate to the mobilisation and management of resources, to organizational processes and procedures and to decision-making processes (McEntire, 2002). Decision-making is an essential part of the emergency management process and phases and it can be problematic in emergency situations for many reasons. Firstly, there is the time factor which is the need to make immediate or quick decisions and this has been found to influence the decision-making process (Buchanan & O'Connell, 2006 and Flueler, 2006). Secondly, emergency situations naturally cause significant stress among decision-makers due to limited situation awareness and the widespread impact that the situation might be causing (Paton, 2003). Thirdly, the level of past experience in managing similar situations also has potential to influence the decision making process (Moynihan, 2008). Fourthly, there is often a limit to the amount of information available. All these factors have been found to further complicate the collaborative process required by multiple agencies in order to provide an effective response (Bigley & Roberts, 2001; Carley & Lin, 1997; Sellnow et al., 2002).

This argument suggests that, the more agencies are involved in EM, the more complicated decision-making tends to be. Although research into decision-making is widespread, it tends to focus on decision-making at an individual level, team or organizational level (Kapucu and Garayev, 2011). While collaboration is fundamental to the command and control structure required for ICS during an EM response (Alberts and Hayes, 2006), it has also been identified as one of the problematic aspects of EM (Bharosa et al., 2009). However, it is worth noting that collaboration presents challenges beyond decision-making (McEntire, 2002). For instance, representatives of many agencies need have a clear grasp of their role, what they are responsible for and what tasks they have to carry out (Dillon et al., 2009). Furthermore, knowledge of an emergency situation needs to be shared and accessible to all responders from the different agencies, in order to facilitate an effective response (Bharosa et al., 2009). However, the entire phase of EM thrives when communication is efficient and the agencies involved in collaboration have a clear understanding of how the other participating agencies are structured (Eide et al., 2012).

In summary, multi-agency collaboration is increasingly seen as vital in emergency management but it presents a range of challenges relating to decision-making, communication, the sharing of knowledge and the understanding of the structure, clarity of roles and responsibilities of the agencies involved.

2.7 Summary

This chapter has examined different definitions and has established that a disaster occurs when vulnerability and hazard interact to cause a severe impact in a location or society. Thus, the goal of disaster management is to reduce the effects of disasters on people and the environment. This chapter has examined approaches used in countries such as USA, Australia and the UK. Each of these countries adopts a holistic approach based on specialized guidelines, in which risk assessment is vital. This research, therefore, focuses on the process of risk assessment, specifically within the UK. The complex organizational structure of risk assessment in the UK, in which regional LRFs are given the task of ensuring preparedness, requires extensive multi-agency collaboration. However, collaboration of this kind poses numerous challenges, as shown in the TRITON exercise. Challenges can make the responses to, and the ability to reduce, the impact of disaster extremely difficult despite the availability of resources. This chapter and the gaps identified from the existing approaches emphasise the need and the requirements for a platform such as one proposed in this research to enhance collaboration beyond the immediate challenges poses. Therefore, the next chapter explores technological solutions available for risk assessment which can also help to reduce the challenges to collaboration, while enhancing the collaboration required for the multi-agency risk assessment process.

Chapter 3: Current Technology Approaches used for Supporting Disaster Management

3.1 Introduction

The purpose of this chapter is to explore the current technology approaches used in the field of disaster management. There are different kinds of technology currently available and these are described in general and then specific examples of software and applications are explored. Additionally, this chapter focuses specifically on identifying the importance of an interactive map in disaster management, preparedness and risk assessment.

3.2 Disaster Management Systems

The following section categorizes and gives examples of currently available technology platforms that are used within disaster management systems. It is followed by an exploration of specific platforms in depth and an analysis of common aspects and weaknesses.

3.2.1 Various Technology Solutions

There is a broad range of technologies that can be used in disaster management for preparing for hazards/threats. According to Cimons (2011), Botterell et al. (2007) and Rao et al. (2007), these technologies can be categorised as Geographical Information Systems (GIS), Remote Sensors, Global Positioning Systems (GPS), warning systems and communication systems. As noted by Rao et al. (2007), a network infrastructure that can exploit technologies such as web, wireless, satellite and mobile can be used to transfer information between agencies efficiently and on time during disasters. In addition to these technologies, mathematical models and simulation software that allow teams to predict the impact of disasters under various conditions can be extremely useful. A summary of the potential use of these technologies with some examples is summarised in Table 3. 1.

Table 3. 1: Brief summary of relevant technologies available for disaster management

Technologies	Use in Disaster Management	Examples
Geographical Information Systems (GIS)	GIS uses geographical location to relate otherwise disparate data and provides a systematic way of collecting, analysing and managing location specific information.	Internet GIS (Peng and Tsou, 2003), Context Discovery Application (CDA) (Tomaszewski, 2008), 3D GIS System (Marchuk et al., 2012) and ArcGIS (Esri, 2012).
Modelling and Simulation	Can be used to predict the social, economical and environmental impacts of a disaster based on mathematical models.	Flood risk assessment in dams' downstream valleys (Viseu, 2007), evaluation of maximum storm wave run-up and surges (Ciaovola et al., 2006), specifying seawall crest levels using a probabilistic method (Reis, 2006)
Warning Systems	Provide means of obtaining information about an approaching emergency and communicating that information to disaster management centres and to those who need to know.	Flood early warning system (rainfall hydrological analysis) (Terzo et al., 2011), Tsunami Early Warning System (TEWS) (Hadi et al., 2012) and GNSS-based geological hazard monitoring system (Li-Yang and Xu, 2011).
Remote Sensing	Valuable in monitoring hazards and assessing damage by using image sensors over an area of interest, collecting optical and radar-based imagery and transforming it into spatial information.	Monitoring of floods using multi-source satellite sensors (Zheng, 2012), wildfire monitoring (Kontoes, 2012).
Communication Technology	Using the internet, mobile wireless devices and satellites, providing a quick way of communicating information to relevant agencies and rapid response groups.	Personal digital assistants for collecting disaster data (Troy et al., 2007), wireless sensor networks (Youssef and Younis, 2008), mobile ad hoc network (MANET) (Niranjan and Ashok, 2011), mobile communication nodes (CNs) based on wireless networks (Gelenbe and Gorbil, 2012), a wireless sensor network based on Zigbee/IEEE802.15.4 standard (Yawut and Kilaso, 2011) and a wireless ad hoc network with

		WINDS (Suzuki et al., 2011).

The technologies presented in Table 3. 1 are not mutually exclusive and can be combined together to create comprehensive disaster management systems. As shown in Figure 3. 1, these technologies can be brought together to produce sub-systems and/or a complete disaster management system. The star diagram in Figure 3.1 represents two main aspects that need to be considered in building a disaster management system: a technology view (sensing, communication, and models & simulation) and an organizational view (structure, process, performance assessment) (Alzahmi et al., 2013). This is because sensing helps to provide a better understanding of location which is key to establishing the context of risk (Lofstedt and Boholm, 2009). Awareness of the risk context is essential in the risk assessment process (Ball and Ball-King, 2013). However, Regester and Larkin (2008) argued that being able to effectively manage risk is based on the capacity to identify, and prevent, the impact of risk. In a sense, it can be argued that this capacity is also based on performance which also includes tangible and virtual capability. While communication is an integral part of the risk assessment and management process, it can be limited or hindered by organisational structure, process and performance (Lundgren and McMakin, 2009).

Within the technology view, the core technologies can be categorised into sensing, communication and modelling & simulation (including GIS). Here the sensing technology allows for the monitoring of hazards and the assessing of damage with the view of communicating this information to the relevant agencies. According to Regester and Larkin (2008), risk and hazard identification and monitoring are insufficient until they are translated and communicated to allow for decision making in order to treat, mitigate or accept risks. Communication technology, therefore, allows and facilitates the transmission of information to the relevant parties (i.e., communities, agencies, government) enabling them to undertake rapid reaction for planning and response (Dillon et al., 2009). Modelling and simulation technologies allow for the integration of various GIS data relevant to disasters and also allow for conducting predictive modelling for planning for disasters. Although this awareness of the functions of GIS data is important, Ball and Ball-King (2013) argued that data or information on any potential danger should be well utilised for the benefit of risk reduction. Haddow et al. (2011), on the other hand, argued that adequate decision making and disaster reduction action can only be undertaken when all information has been well integrated. Therefore, the integration of these core technologies are important for disaster management systems because they can result in three main functional systems:

1) sensing and communication technology can be used to establish early warning systems
2) the sensing of disaster events and models & simulation can be used to create systems that allow agencies to contextualise an incident,
3) Communication and models & simulation can be used by agencies for collaboration during incidents (Alzahmi et al., 2013).

Regardless of these functional systems and their ability to enhance the risk assessment process, it is also important to understand the components of the organisational view. For instance, the organisational structure determines how roles, power and responsibilities are assigned, controlled and coordinated, and how information flows between the different levels of management (Jacobides, 2007). Given this notion, the process required for effective risk assessment which informs the disaster management process can be described as a network of activities, power, roles and responsibilities that can be mapped out for a clarity of purpose and decision making. Thus, the organisation's disaster coordination process provides a 'map' of activity which documents roles and responsibilities in the event of a disaster. According to Haddow et al. (2011), any disaster management measure should provide a well-coordinated, consistent and transparent process for all the stakeholders (acting at various points throughout a disaster management cycle) as well as a point of reference for management decision-making. The mitigation, preparedness and response measures recommended by Alexander (2002; 2006) and Haddow et al. (2011) all emphasised this; however very little was debated concerning determining the capacity of organisations to carry out the level of integrated measures or decisions required for disaster management. While the capability assessment framework provides tools for assessing the organisational capabilities for responding to disasters (GAO, 2014), collaboration leading to the onset of the incident can still be a challenging process (Alexander, 2006). Thus, the significance of capacity assessment is that it allows organisations to assess their degree of preparedness in terms of resources, planning, and training (Alzahmi et al, 2013). However, the ability to effectively integrate, collaborate and conduct an adequate capacity assessment of all organisations for the risk assessment process can be challenging and demanding, which justifies the need, relevance and importance of the disaster management system illustrated in Figure 3. 1.

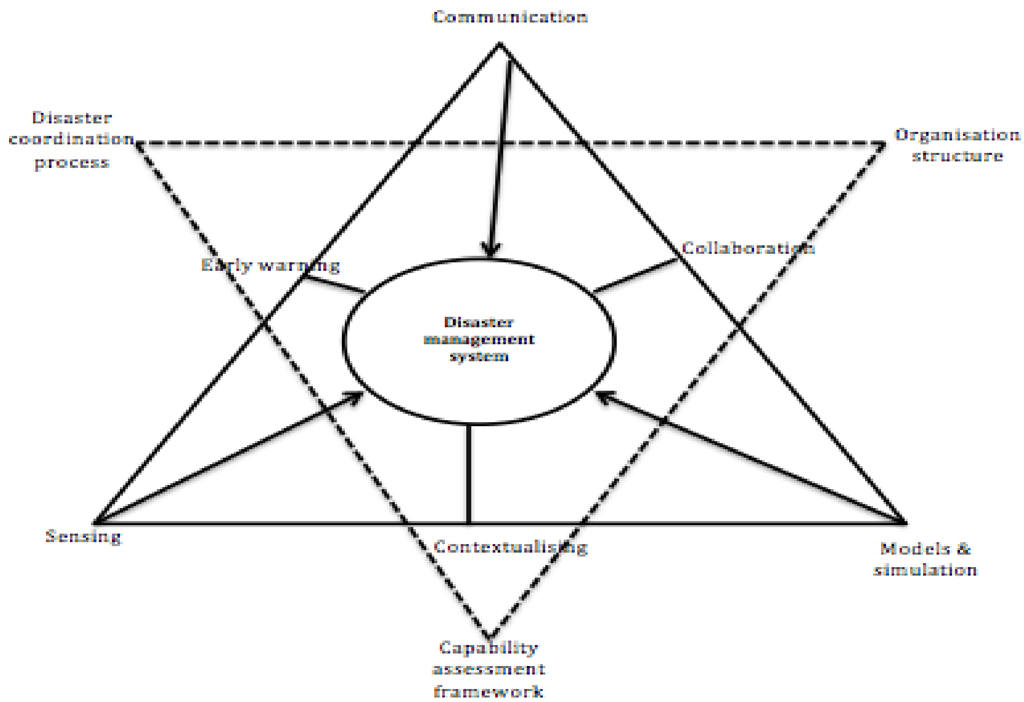


Figure 3. 1: Components of a disaster management system

As seen in Figure 3. 1, the diagram shows the flow of interactions between the disaster coordination process, the organisation structure and the capability assessment framework. Having the capability assessment framework at the base of the triangle illustrates the crucial role it plays in strengthening the information disaster coordination process and in its ability to integrate organisations irrespective of variations in structure for risk assessment goals and purposes. Evidently, other components such as early warning, collaboration, contextualisation and models, and simulation enhances disaster coordination, organisational structure and the capability as shown by the inner lines within the Figure. The three hierarchies of activity theory as explained by Kuutti (1996), i.e. activity, action and operation and the corresponding terms such as motive, goal and conditions, influenced the selection and arrangements of the elements in Figure 3. 1.

Therefore, Figure 3. 1 illustrates the levels and the network of interactions required for integration, for the risks' assessment process and for coordination in a disaster management system; a design which was possible through the application of activity and critical thinking theories.

3.2.2 The Potential of Technology in Assessment and Preparing for Disaster

Technology has a vital role in managing disasters effectively and efficiently (Alexander, 2009). The added value of technology (such as the Internet of Things, cloud computing, web technology, GIS (geographic information technologies), mobile information technology, remote sensing and satellite) is in assisting in the reduction of the impact of a disaster as well as making data available to managers to guide them on how to react in an emergency incident. Technology offers an understanding of a natural or man-made environment and assists in managing the process of an operation, organizational operations, preparing for disaster management (Alzahmi et al., 2013). The role of technology in enhancing situational awareness and in analysing/summarising information for strategic planning in order to optimise the risk assessment and preparation in the disaster management life cycle have also been emphasised (Alexander, 2009). Table 3. 2 below shows the functional requirements needed for handling various disaster types and the role of technology in disaster management systems (Alzahmi et al., 2013).

Table 3. 2: The functional requirements needed for handling various disaster types

Disaster type	Sub-disaster name	Functional requirements within a disaster management system	Use of technology
Natural	Natural phenomena beneath the earth's surface Topographical phenomena	Marking areas of risks, potential structural damage, impact on critical infrastructure, demography, evacuation planning. Sensing, warning.	Raising awareness, communicating risks, assessment of potential damage, testing evacuation procedures, training. Contextualising incidents during disaster and monitoring progress.
	Meteorological/hydrological phenomena	Risk assessment of critical infrastructure, evacuation planning. Sensing, warning. Source, depth, velocity, flow, structural damage, impact on critical infrastructure, evacuation planning. Sensing,	Assessing the vulnerability of critical infrastructure, testing evacuation procedures, and training. Contextualising, monitoring.

		warning.	Raising awareness, communicating risks, assessment of potential damage, testing evacuation procedures, and training. Contextualising, monitoring.
	Biological phenomena infestations	Location of incidents. Spread of infection over time and space. Sensing, warning.	Ability to see patterns of movements. Contextualising, monitoring.
Man-made	Socio-technical technological disasters	Location, impact on critical infrastructure, evacuation planning.	Assessing resilience to attacks, testing evacuation.
	Transportation disasters		
	Stadia or other public places' failures		
	Warfare divided into: 1.National 2. International		
Hybrid	Natural and man-made events	Exploring possible hybrid events and their impact.	Conducting 'what if' scenarios and ensuring disaster teams are prepared to handle multiple disasters.

Table 3.2 shows the roles and functions of technology in disaster management and also indicates the relationship between different types of events and the functional requirements that can ensure effective risk assessment.

3.2.3 Current Systems

Various commercial systems have been developed and are currently used in different countries to support disaster management and risk assessment. A description of these systems follows.

3.2.3.1 HYDRA-MINERVA System

One example is the HYDRA-MINERVA system used by the UK fire and rescue service. The focus of this computer tool is explicitly on simulating emergency situations such as fire, chemical spills and heavy snowfall and, therefore, on increasing preparedness and on aiding decision-making in real events. As a training tool, the programme logs decisions that have been made and then uses them to create a debriefing in which they can be assessed. Information is fed into the simulation in real time from many different sources (http://www.hydrafire.org/). A similar simulation tool, but designed exclusively for flood hazards, is FloodViewer. It allows users to visualise the impact of different levels of flooding, using mapping and animation (Halcrow, 2011).

3.2.3.2 Incident Command Administrator and Gaist Emergency

The commercial market for platforms which facilitate multi-agency risk assessment has grown in recent years. Gaist, a UK consultancy firm and software developer, has created a number of products such as Inca (Incident Command Administrator) and Gaist Emergency. The latter is specifically marketed as a multi-agency tool and features a universal display and interface and access to online maps (Gaist, 2010). Gaist Emergency has compatibility with the Inca programme which means that users can access information from Gaist Emergency (which can inform the decisions they make) and execute using Inca (Alexander et al., 2011).

3.2.3.3 MOSAIC Software

Socio-demographic information, a key element of risk assessment, has provided the basis for a range of commercial products with an appeal for multi-agency teams (Experian, 2009). Experian's MOSAIC software is one example. It brings together a range of demographic, lifestyle and behavioural data from census responses, media and market research (Experian, 2009). Although primarily intended for use in commercial and business planning, the programme has been used by the fire and rescue service in targeting public information communication activities. The potential use of such information in multi-agency planning is clear; by providing information about the population of an area and its movements, the software can help multi-agency teams assess risk, estimate potential casualties and loss of life, and prioritise their responses (Alexander et al., 2011).

3.2.3.4 Atlas Incident Management System (AIMS)

The 2004 Civil Contingencies Act is identified as the impetus for the creation of the AIMS ATLAS system. As previously noted, the Act gave local authorities legal responsibility for better preparation for, and response to emergencies. AIMS ATLAS is intended to replace paper-based emergency logging systems used by local councils. In the past, information was recorded and disseminated on paper. It was noted that this could be confusing, time consuming and liable to result in the loss of important information, especially in a busy, stressful emergency situation in which new information constantly appears (Atkins and Partners Ltd, 2006).

AIMS ATLAS is a piece of computer software for use in local authority emergency control centres which aims to organize and store information electronically, allowing organizations to "effectively manage and coordinate their response during an emergency". Its general purpose is to help with the coordination of an emergency response, aid the assessment and evaluation of an emergency in real time, and to provide access to existing emergency plans and information. Moreover, it can organize all incoming information into a log which can be used during and after an incident. It allows responders to understand their roles and responsibilities in an incident. The software is explicitly intended to promote and support collaboration and coordination between and within different agencies (Atkins and Partners Ltd, 2006).

The system records every incoming and outgoing message, as well as actions taken, on a log. This helps during an emergency but afterwards also helps to evaluate performance and suggest improvements. It allocates response tasks to different individuals or departments. Moreover, it allows users to filter the information they view depending on their task and role. The programme also generates situation reports and enables the communication of these reports by email. Furthermore, it provides access to emergency plans and contact information online. It gives users access to different key areas of information and communication such as events, briefings, tasks, messages and plans (Atkins and Partners Ltd, 2006).

3.2.3.5 CLIO

CLIO is a commercial software system developed with input from emergency responders such as the police and other emergency services. It was developed by Badger Software, one of the main suppliers of emergency management software in the UK. The system aims to provide a means for the successful sharing of information in real time, giving responders immediate access to information and plans in order to ensure co-ordination between responders (Badger Software, 2013).

In the preparation stage, the software can be used to create and store emergency plans. In addition, the system allows for the testing and evaluation of these plans. During an emergency, users can work on an interactive map from different locations so that all staff can share real time information and thus respond effectively and efficiently to incidents.

The system can be used on an internal network or via the Internet. This allows users to access it on a number of different devices such as PCs and smart phones. The system is intended to increase situational awareness between responders.

The CLIO system allows for emergency plans to be put into practice in a time of emergency, automatically allocating tasks and providing advice to staff members during an incident. The system is controlled centrally, but all users can interact with each other using the platform. Moreover, all actions that have been taken are recorded which can be used when the 'lessons learnt' are evaluated after an incident (Badger Software, 2013). CLIO is used by a number of organisations ranging from police forces to private businesses. While it was not developed specifically for multi-agency response activities, it has been used by LRFs in different areas in planning and preparation for incidents.

Overall, both of these platforms (CLIO and AIMS) can be used during an incident to record actions taken and to share information between responders. Both are accessed by the Internet and store information electronically. However, CLIO can be used in preparation for incidents in creating plans and testing them. In providing a single platform for the sharing of information, both of these can be used to enhance collaboration between responders.

3.2.3.6 Depiction Mapping Software

In the USA, mapping software called Depiction is used to plan, prepare and respond to disasters and other events. It is designed to be used not only by emergency management professionals but also by concerned members of the public. The software allows users to visualise how a disaster might impact a home, neighbourhood, community or business. It also shows infrastructure and resources, simulates what might happen and allows users to prepare and respond for any eventuality (Mastin, 2010). Furthermore, users can explore scenarios offline as well as online, in case the Internet is not available. The latest version automatically integrates the US National Weather Service 24-hour forecasts into the active maps of any local government, planning agency or concerned citizen, and includes interactive map elements such as water flooding over roadways, downed power lines, power outage reports and landslides. Moreover, the software searches for relevant information on the internet specific to a particular region, such as satellite images, street maps, road networks, forecasts for precipitation, temperature and winds. As a result, it can be customized to show elements such as evacuation routes, blocked roads or possible flood levels, and then shared with other interested parties. Figure 3. 2 shows Stillaguamish River flooded in January 2009 in the USA.

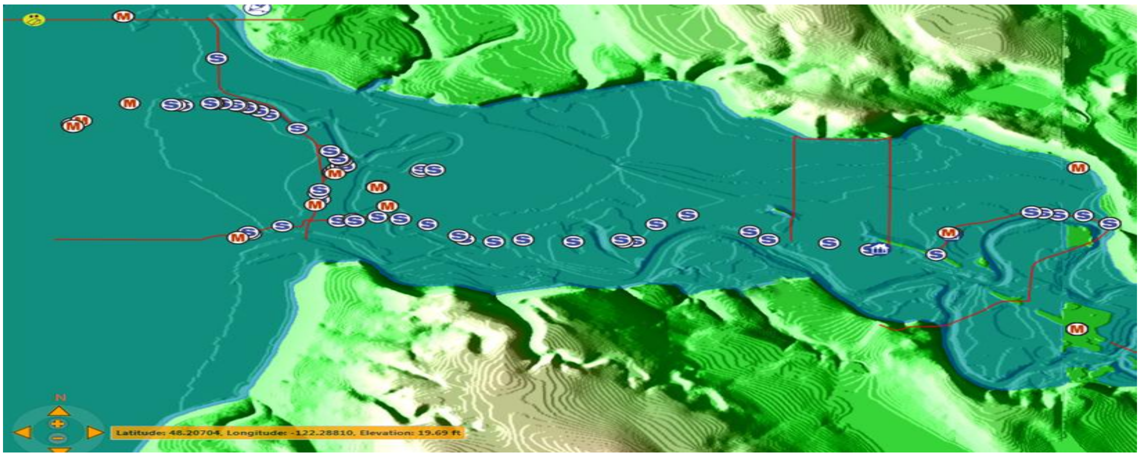


Figure 3. 2: Stillaguamish River flooded in January 2009 in US as shown by the Depiction Mapping Software (Source: Seattle, WA (PRWEB), 2009)

Depiction mapping software is quite distinct in its use as a tool in disaster management. Its ability to search for relevant information specific to a given location on any hazard and its impact on the environment is useful for deciding risk mitigating measures. Similar to this, is another software (GIS) that is designed to capture, process and produce hard copies, when needed, of the geographic information of a location. The next subsection examines the different facets of GIS which is a more comprehensive model which is known for its role in facilitating integration with other systems in disaster management.

3.2.3.7 Geographical Information System (GIS)

A Geographic Information System (GIS) is a computer system that is used to capture, store and analyse data and information with a geographical aspect. The actual system consists of hardware (computer and peripherals such as scanner and printer), software and data that are stored on the computer. Users will use the software to analyse the data (Eldrandaly, 2007). The geographical aspect of GIS data means that all data accessed is related to co-ordinates in 3D space and refers to a location on the earth. The area that the data represent can be a point, a line or an area (Mark, Chrisman et al. 1997). Figure 3. 3 shows the different GIS information layers, gathered together.

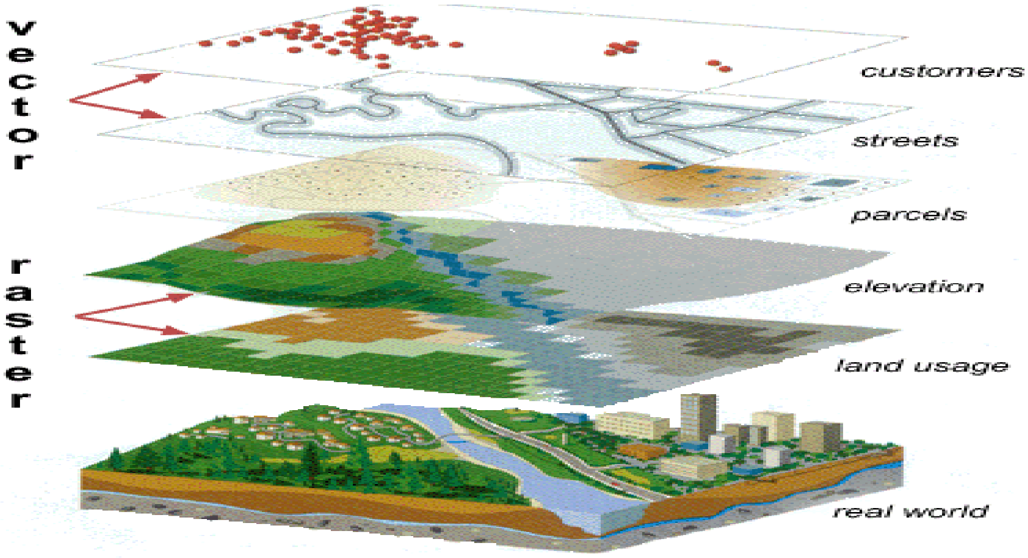


Figure 3. 3: Different GIS information layers, gathered together. (Source: National Coastal Data Development Centre (NCDDC), National Oceanic and Atmospheric Administration (NOAA), USA)

GIS is an essential tool for supporting disaster management process mitigation, preparedness, response and recovery. This research focuses on the preparedness phase, specifically in the risk assessment domain. This section presents a review of the state-of-the-art GIS products and geospatial information widely used in the disaster management preparedness phase and in the risk assessment domain.

According to Waugh (1995), “GIS uses geographic location to relate otherwise disparate data and provide a systematic way of collecting and managing location specific information.” Used in disaster management, GIS digitally captures, stores, analyses and manipulates data (Senior and Copley, 2008). It is for these qualities, and its ability to display geographical information quickly, and present it in an understandable format, that GIS is considered critical for disaster management functions (Cutter et al., 2007). As stated by Jung et al. (2014), GIS is used to create and combine the various components of inundation maps and flooding maps (which indicate which areas would be flooded in a particular flood event). Practically, these maps are made up of layers of GIS providing bathymetric, topographic, land use and inundation projections. Recently, Bhattacharya et al. (2012) described GIS as a powerful data management tool that strings together unconnected data sources for quicker analyses, and for the organization and sharing of information.

Additionally, not only does GIS provide a graphic user interface that enables the user to quickly navigate through geospatial data (including complex three-dimensional datasets), it also enables organizations to visualise and maintain overall situational awareness during normal operations and emergencies; GIS is flexible technology enabling full integration with other information systems. There are many examples in the literature that address the use of GIS in disaster management, amongst which are Internet GIS as a network-based geographical information service (Peng and Tsou, 2003), Context Discovery Application (CDA) (Tomaszewski, 2008), 3D GIS System (Marchuk et al., 2012) and ArcGIS (Esri, 2012).

a. 3D GIS System

The World Agency of Planetary Monitoring and Earthquake Risk Reduction (WAPMERR) has developed a 3D GIS Research and Information System for the purposes of reducing risk due to natural and man-made hazards and for post-disaster rescue planning. As indicated by Marchuk et al. (2012), this 3D GIS system has global coverage, full three-dimensionality and is able to manipulate 3D models of buildings. Other features include a digital cartographic base design using satellite images, digital what, elevation and bathymetry models, a database management system for visualization, and software for the numerical modelling of geophysical processes/phenomena and the handling of historical hazard data.

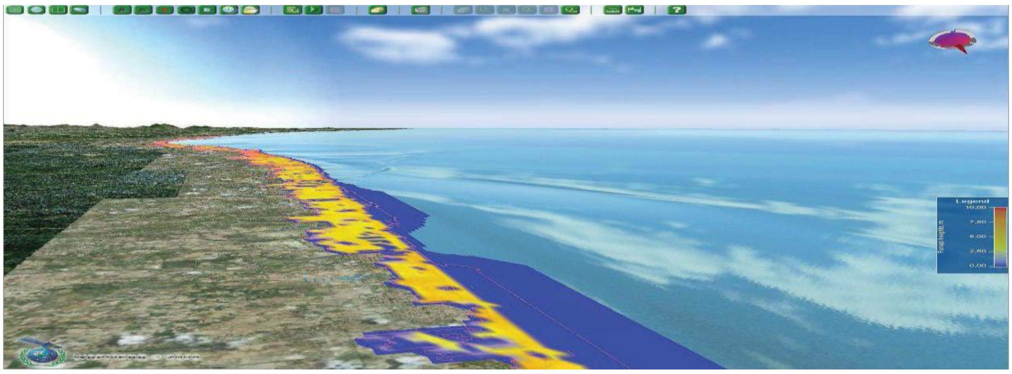


Figure 3. 4: An example of a flooding map of Nagapattinam, India (as shown by WAPMERR) (Marchuk et al., 2012).

Figure 3. 4 shows the GIS's power of precision which enables the software to capture information and model it in 3D. For instance, the ArcGIS is designed in such a way that it can support organisational tasks for disaster management. This is further explained below.

b. ArcGIS for Disaster Management

As stated by Esri (2012), ArcGIS for disaster management is designed to "organize and deliver the baseline tools and data typically needed to support a disaster management organization." From planning to response and recovery, ArcGIS supports and enables common workflows across all aspects of the mission. ArcGIS provides, amongst other characteristics, public safety-specific features for operational data, a common analytic tool and model for risk assessment, vulnerability analysis and impact assessments, a situational awareness viewer that supports mission-specific delivery of data and tools, configuration guidelines for common authoritative data sources, mobile projects, a public information map that integrates social media and data exchange, and a catalogue portal for collaboration and data discovery.

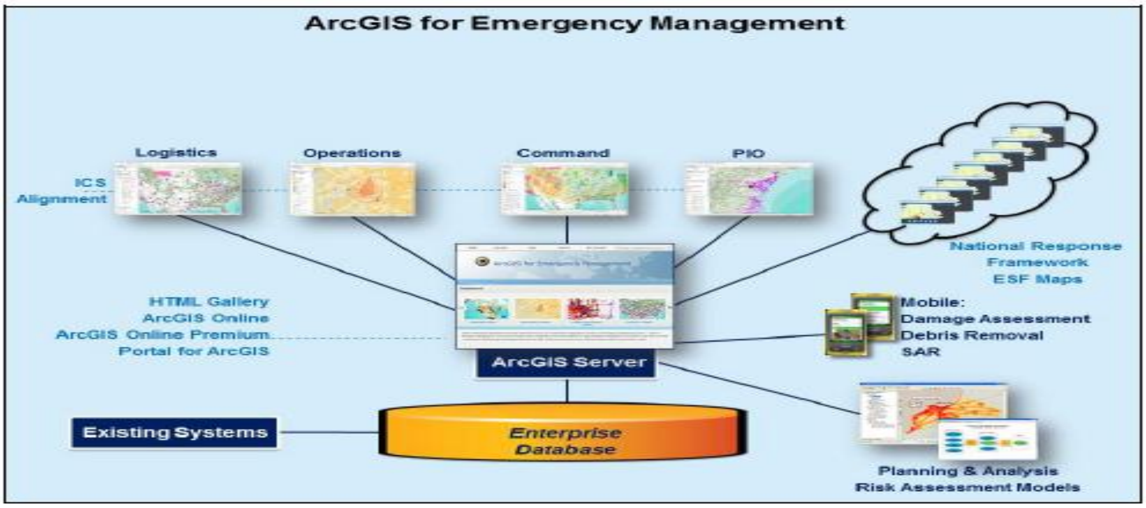


Figure 3. 5: Baseline configuration of the ArcGIS platform that works with a common emergency management organization structure and mission (Esri, 2012).

Figure 3. 5 illustrates the interactions between logistics, operations, command and other components required for emergency management. Ensuring adequate interaction is crucial for implementing a national response framework. However, it is important to know that the ArcGIS platform can work on different gadgets which facilitate planning, analysis and risk assessment models. Regardless of this, the functionality of the ArcGIS platform is based on its compatibility with the existing systems put in place for emergency management. As a whole, the GIS software has many functions and advantages. However, it lacks the essential components shown in Figure 4.1 which links the main elements that facilitate the collaborative risk assessment process in disaster planning.

3.2.4 A Comparative Summary

Maps are the most commonly used tools for understanding spatial information in commercially developed software. Technical platforms that have been developed to support collaboration among responders include the Atlas Incident Management System (AIMS) and CLIO, both of which can be used by responders to share information electronically using the Internet. Also there are several frameworks are used by different organisations to enhance risk assessment such as the HYDRA-MINERVA system, (Incident Command Administrator), Gaist Emergency and MOSAIC software. Many developers offer users tools to visualise and analyse layers of data on a mapping system, in single and multi-user environments (Booth and Mitchell, 2001).

The HYDRA-MINERVA system used by the UK fire and rescue service simulates the emergency situations (such as fire, chemical spills, heavy snowfall and incidents) to which the fire service in the UK responds. While it is used to increase preparedness of response, it is more reactive to the occurrence of emergency. While it allows different level of impacts to be visualised, it is not exactly designed for risk assessment and mitigation. The Inca and Gaist emergency tools, being multi-agency tools, have a universal display and interface linked to online maps.

While the issue of safety of usage and access to a confidential decision making process is not mentioned, the former informs decision making while the latter supports the implementation of decisions. Similar to the HYDRA-MINERVA system, the Inca and Gaist tools also focus on the reactive process and on action to deal with the impact of risks and not on their prevention and mitigation. These two tools also fail to establish the context of risk(s) which is the initial stage that helps to determine the appropriate ways for the risk assessment process and how the stakeholders should be involved (Lundgren and McMakin, 2009).

MOSAIC software, on the other hand, is superior in helping to identify and establish the context of risk as well as assisting in monitoring risk patterns in a target population or location. This tool is key to the inception of the risk assessment process, but is limited in ensuring that the capacity for the required response for risk assessment amongst agencies is assessed and determined. The AIMS ATLAS system, being a virtual replacement for paper documents and plans, provides a clear purpose for its functions. While the intention for developing the AIMS ATLAS system was to reduce time, confusion and stress during an emergency situation, and the possibility of loss and liability during critical incidents, it is also limited to a reactive mode for disaster management.

The AIMS ATLAS system in use by local authority emergency control centres is also limited and restricted to a specific location; this restrains its use during the planning phase and its use as a tool for integrating and collaborating the risk assessment process. Its function and relevance is limited to the response and post response phases for debriefing and for the assessment of the responsibilities of Category 1 and 2 responders. CLIO may be considered as an improvement on the AIMS ATLAS system since it can be used by responders such as the police and other emergency services. As it can be used by the police (who are mobile during an incident), this means it is not restricted to a specific location. Being able to draw on emergency plans for response during an emergency situation is also an improvement.

However, it is also a reactive tool, rather than a tool which can be utilised for the collaborative risk assessment process between multi-agencies. The benefits of the CLIO system are undeniable but its limitation in not being able to establish the context of risk, analyse risk and evaluate risk is a major drawback in the risk assessment process both for agencies and stakeholders who are responsible for planning and response. Depiction mapping software is another software or tool that is examined in this section. The tool is known for its ability to help determine and assess the impact of a disaster on homes, locations or businesses. However, this tool also focuses on impacts, not on the wider consequences as required for risk assessment process (Lofstedt and Boholm, 2009).

Although GIS is a more comprehensive model that supports the mitigation, preparedness, response and recovery phases of disaster management, it is identified by the researcher as being too comprehensive since this research focuses on the preparedness phase especially the risk assessment domain. Therefore, by examining these disaster management tools, it is evident that gaps still exist - in terms of technology - for risk assessment that ensures integration and collaboration between multi-agencies in order to obtain a more adequate response. Additionally, examining the current tools available for disaster management systems has helped the researcher determine the essential features and components required for the collaborative risk assessment process by agencies and stakeholders responsible for disaster planning and response.

3.3 Limitations

Fleischauer et al. (2006) noted that spatial mapping is often not implemented to its full potential. There are a number of possible reasons for this. Van Westen (2013) suggested that the assessment of multiple hazards requires a great deal of information, not all of which is available or accessible. Obtaining such information can also prove to be costly. Moreover, even when such information is available, the incorporation of cascading effects is difficult and there remains a lack of research into how best to map and assess the risks presented by multiple hazards. Decisions about how to categorise the information available are problematic and difficult to transfer into a form that practitioners and stakeholders can use (because of the complex nature of the interactions between a user and the platform with which they are working) (Van Westen, 2013). Alexander et al. (2011) pointed out that training is required even for the simplest of systems.

The information required by a disaster management system is a deeply problematic issue. There is a generally difficult balance to achieve between the need for comprehensive data and the need for a user-friendly platform. The data needs to be simple enough to be used effectively, but not too simple so as to make it useless. Moreover, risk assessment is based on both hazard data and vulnerability data. These kinds of data can be difficult to link. This is because hazard data can be dynamic and changing, whereas vulnerability data is often based on information that is only collected periodically, for example in censuses. Furthermore, due to its nature, risk assessment has a strong element of uncertainty. This poses problems for the designers of systems because this uncertainty needs to be represented but not in a way that restricts risk assessment activities by adding too much confusion for users, especially when users have to collaborate (Alexander et al., 2011). Therefore, the purpose of this research is to conduct an in-depth analysis of the data required by agencies to conduct risk assessment and the presentation of this data through an easy to use interactive map to enhance collaboration among agencies. This research, therefore, aims to build upon the existing technology, but also plans to bring the technology closer to the users and to the risk assessment process itself.

3.4 Importance of Interactive Maps

Maps are amongst the oldest and most popular forms of graphical communication and they are highly regarded for their efficient information transfer. However, irrespective of the efficiency of two-dimensional maps, three-dimensional interactive maps offer significant benefits and improvements over their traditional counterparts. According to Peterson (1995), a map is interactive if it includes a user interface with graphical icons and tools for users to interact with the map, a pointing device and the almost instantaneous display of maps. The term ‘interactive maps’ is used here to refer to different types of interactive geo-applications where a map displays play a central role. The use of interactive maps enables authors to enrich and extend their work, providing a means to highlight their findings in a way which is visual and easily accessible, thereby allowing the reader to quickly comprehend the relevance of a paper and visualize research data.

The importance of interactive techniques in mapping has been gaining recognition since the 1970s (Moellering, 1975). According to Nielsen, “interaction possibilities are often being considered as the most important user question, because the interaction between computer and user is vital to the relevance of digital systems,” (Nielsen, 2004). Moreover, in general, 3D maps allow for more accurate identification of positions. Results suggest that they are better for understanding distances, environment and topography, while 2D maps allow for better recall of place names (Kraak, 2006). One of the most well-known interactive maps is Google Maps. This online mapping service (which provides interactive maps and satellite/aerial imagery information around the world) is user-friendly with easy panning and zooming undertaken through a mouse or keystrokes. Street names and road outlines are displayed and a search ability allows searching for everything from the name of a business or point of interest to a city or an address (Haklay et al., 2010).

Google Earth goes a step further by using maps, geography and satellite data to build a virtual globe. Users enter the name or address of a location and are given full access to the geography, sites and physical components of an area. 3D mockups of buildings, historical imagery, satellite views, and perspectives of the skies and oceans can also be accessed. Able to handle an impressively large dataset over the internet at an acceptable speed, Google Earth has a convenient layers’ feature: a list of common search items that can be overlaid on any satellite image, such as a road, bank or shopping centre. Google Earth differs from Google Maps in that it combines a graphical information system (GIS) and satellite photos and provides terrain and building visualisation (http://urbanplanningblog.com/2006 /08/22/the-wonder-of-google-earth/).

Via maps, GIS has the power to visualise the results of decisions and deliberation processes (Ramsey, 2009; Couclelis and Monmonier, 1995, and Elwood, 2006) allowing users to perform tasks and activities in an intuitive and efficient way. Furthermore, in the context of flood hazards' management, GIS provides a fast and powerful tool which can be used to create interactive map overlays showing precisely which areas of a community are in danger of flooding. Such maps can then be used in mitigation efforts before an event and for recovery after the event (Awal, 2003). As an example, Figure 3. 6 illustrates the Flood Simulation of Brisbane which was used extensively by the Australian and global media during the recent flood crisis in Brisbane in January 2011. The flood level simulations were produced interactively. This was a very effective way of communicating the impact of a flood on buildings and infrastructure and it provided a valuable tool in assessing the potential risk for the city in the days leading up to, and during, the flood peak.

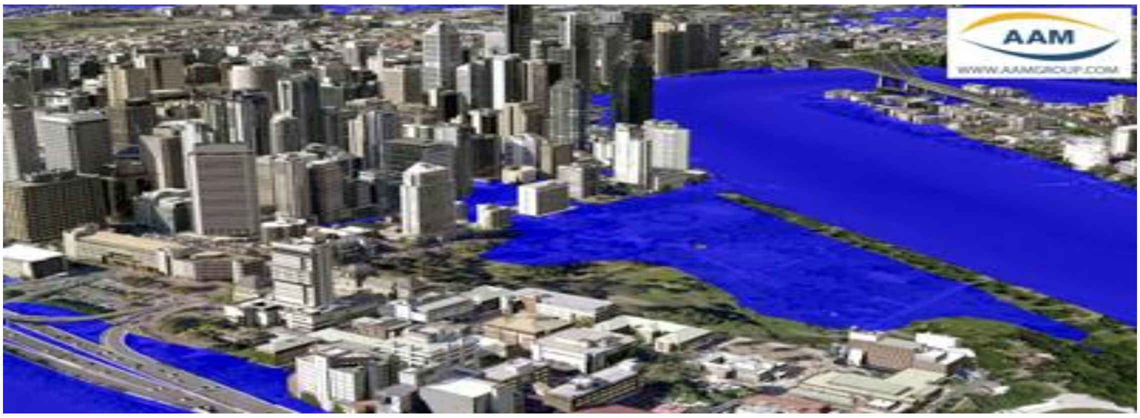


Figure 3. 6: 3D Flood Simulation of Brisbane 2011.(Source: GISCafe, 2011, AAM Modelling Aids Brisbane Flood Crisis).

Interactive mapping tools can be also used in environmental planning and impact assessment, oil and gas planning and simulation, wind farm and offshore turbine planning, ocean management and geology (Gold and Condal, 1995; Goralski and Gold, 2007b). When combined with data mining, interactive maps provide a highly effective and powerful exploratory environment for large spatial databases (Andrienko et al., 2001; Guo 2003; Koua and Kraak, 2005). According to Roth (2012), interactive maps may support or even enhance a map user's ability to uncover unknowns about the map data by encouraging interactive exploration of the data. The provision of multiple representations of map data, enabling readers to see changes in spatial patterns or distributions, is one method of promoting this exploration. Pelzer et al. (2015) added that map legends should be interactive, linking the legends to the display of the map content thus enhancing their explanatory power. An interactive mapping device, therefore, is the interface between spatial information and participants.

In geovisualisation (the interactive exploration of geographically-referenced information graphics) (Slocum et al., 2005), a map may provide a realistic reconstruction of a city or a planned landscape, as in geospatial virtual environments (GeoVEs) (MacEachren et al., 1999). Indeed, GeoVEs visualizations are used for urban and landscape planning and environmental impact assessment, amongst other things. Furthermore, such maps have also become indispensable as interfaces for many complex systems.

This interaction is important not only for the need to overcome the limitations of 3D presentations but also to increase the efficiency and usability of maps. Moreover, an important role of maps is to support visual thinking and decision-making. As pointed out by Gold when discussing a decision support system for forestry planning, for decision systems in general, "it is necessary that the interaction be simple and rapid, permitting the suggestion of several 'what-if' queries in a short time period, while the manager is actively engrossed in assessing a particular problem" (Gold, 1993). Equally, Sieber et al. (2013) pointed out that the process of visualisation requires a high level of interactivity. According to Kraak (2006), "three dimensional displays require an interactive viewing environment that allows one to view the objects from any direction to avoid obstruction and allow the query of all objects in the representation."

Although more tests are required, indications are that maps offer significant benefits, efficiently and reliably transferring information while supporting spatial reasoning and offering a practical means for engaging the users (Kraak, 2006). In the words of Kraak, "the availability of a three dimensional world that can be queried, analysed and viewed would improve insight and is likely to result in better decisions" (Kraak, 2006).

3.4.1 Visualisation

Alongside the commercial growth of computer software that can aid multi-agency emergency management teams, the last twenty years has seen a technological growth in the area of visualisation (Maceachren, 1998). The ability to map and visualise areas and situations is of great use for multi-agency teams and their work in planning responses to disaster. Geographic Information Systems (GIS) have brought about a shift in how spatially-referenced data can be stored, depicted and analysed and in how users can interact with the data.

An obvious area of interest for multi-agency disaster management teams is mapping. Mapping has become the keystone for risk assessment and communication. Indeed, it has been shown how a map is presented and, therefore, visualised has an important effect on how the user is able to communicate the information presented by the map (Alphen et al., 2009). Although computers can create photo-realistic 3D models (Kot et al., 2005), what is most important is the user's ability to manipulate maps to highlight and emphasize the most relevant information for their purpose (Maceachren and Ganter, 1990). This can be done by altering scales and using symbols.

Basically, there are two ways of approaching mapping which can be used as part of a platform for multi-agency emergency planning. Firstly, the 'communication approach' stresses the need for maps to accurately represent and display the reality of an area. On the other hand, the 'visualisation approach' suggests that maps can also be used to predict and simulate hypothetical events (Maceachren and Ganter, 1990). The main concept in the first approach is to transfer what is known about an area or situation. However, mapping can also be used to encourage users of visual thinking about a problem in a new, visual way (DiBiase et al., 1992) and, therefore, possibly come up with new solutions to a problem. It has been suggested that interactivity, an effective user interface and visualisation tools can encourage users to be more flexible in their approaches to problems (McCarthy et al., 2007). Underlying this is the view that the user of a mapping programme should be thought of as an active participant and not just as a passive receiver of information (Morss et al., 2005) especially given that multi-agency decision-making is an active, dynamic process.

3.4.2 The Importance of Visualisation in Risk Assessment

Disaster is a function of a range of factors (such as hazards, human vulnerability and lack of capacity) while risk is defined as the expected losses (such as lives, personal injuries, property damage and economic disruption) due to particular hazard for a given area and reference period. Risk, therefore, is the product of hazard, vulnerability and coping capacity (WMO, 2002).

One of the key elements within a disaster management strategy is risk assessment. Consequently, in dealing with issues such as accepted levels of risk and identification of areas at risk and those vulnerable, risk assessment allows for better mitigation and preparation through increased risk awareness as a critical element in the preparedness phase. It is also vital that risk assessment is understood and communicated in an appropriate way (U.S. Department of Health and Human Services, 2002). Furthermore, studies have shown that the presentation of hazards, vulnerability, coping capacity and risk in the form of digital maps has a higher impact than traditional information representations (Martin et al., 1997; Husdal, 2001). As a result, with the increasing use of digital maps by disaster managers, it is expected that visualisation, provided in the proper way, has the potential to be a highly effective communication tool (Kolbe, 2005; Marincioni, 2007; Raper, 1989; Zlatanova et al., 2002a). In order to achieve a good standard of 3D visualisation, two aspects must be observed: appropriate presentation and appropriate tools for interactions. According to Kemec et al. (2010), urban modelling is generally a holistic process of conceptualisation, data capture, sampling and data structuring, depending on the aim of visualization; in risk management, 3D modelling is very much dependent on the kind of disasters represented and the kind of users involved in the risk management process.

Interactive hazard maps provide an effective medium for visualising risk information and bridging communication barriers among varying stakeholders. Moreover, these maps aid in the assessment, analysis and mitigation of risks (Dransch et al., 2005). When fabricating a hazard map, one must keep in mind the purpose of the map, the intended audience, how data will be displayed, and where it will be used (Friedmannova et al., 2007). Also the creation of effective interactive hazard maps takes into consideration community knowledge through the utilisation of participatory mapping methods. These methods aim to involve locals in the mapping process, to reflect local views in governmental policy, and to develop a mutual understanding of surrounding risks (Institute for Ocean Management, 2007). If constructed appropriately, community-based hazard maps can help bridge the knowledge gap between community members, local governments, non-governmental organizations, and members of the international disaster response and risk reduction community. As a result, efforts continue to educate local communities in the utilisation of hazard maps in order to identify vulnerabilities and increase communication among stakeholders.

3D models are also used by urban vulnerability analysts for correlating societal and biophysical factors when working in unfamiliar locations (Rashed and Weeks, 2002; Whiteman, 1998; Lagorio, 2001). Additionally, Alexander (1993) and Shaluf (2007) have identified urban vulnerabilities as a spatial science and as having geographical concerns, for instance: Urban objects (such as residential and commercial buildings, pedestrians and vehicles), urban features (such as, shops, roads, pavements) and Natural features (such as green spaces, rivers and the seismic vulnerability of places}.

These “urban ensembles” (Benenson et al., 2004) (such as buildings, streets, bridges, roofs, facades and green spaces) are obviously highly interrelated and can be visualised using design plans, drawings and video data records (Pissinou et al., 2001). Furthermore, various layers such those giving information on houses and industrial sectors can be overlaid together for visualization and subsequent spatial analysis. Some researchers have used simulation methods to view the roles of these ensembles in urban amenities (Torrens, 2006). Rasheed and Week (2003) related urban vulnerabilities to natural hazards such as earthquakes and to human behavioural adaptations. They argued that urban vulnerabilities are intertwined with socio-economic systems.

Researchers have also found visualisation techniques useful in examining the effects of adjacency (what is next to what), containment (what is enclosed by what), proximity (how close one geographic object is to another), accessibility (how an object can be reached from a certain road) and visibility (how far certain objects are visible from certain locations) (Pullar and Egenhofer, 1998). However, as in simple two-dimensional features, it is essential in 3D features to either associate distance or direction with an object, or to compute the distance and direction between, for example, roads and houses along with the height or depth of individual objects. This requires the storage of extra attribute information, i.e., latitude, longitude, height or depth (and/or time). In earlier times, 3D visualisations were possible only in computer-aided design (CAD) (Lee, 2007; Zlatanova, 2000) and cadastral mapping (Billen and Zlatanova, 2003). Today, ArcGIS 9.4 beta version incorporates 3D functions in its Network Analyst (ESRI, 2010) making it accessible and functionally more useful to planners and researchers alike within accessibility analyses (Kwan, 2002).

Others have used 3D visualization to display remotely sensed images and to analyse ozone and nitrous oxide concentration and dispersal patterns (Matejicek et al., 2006). The use of 3D is also increasing in transportation planning with the use of a lane-oriented, road-network model (Demirel, 2004). Interactive maps have not only increased the understanding of planners and experts in the field of disaster management but have also caused an increase in the interest of the participating public through better visualisation and by allowing direct participation with the models (Shen and Kawakami, 2010).

3.4.3 Interactive Map Data Analysis

Interaction with map objects, as described above, is a part of a broader category concerning interaction with data in general. Other parts of this broader category concern different types of interactive data analysis, i.e., the use of special tools to facilitate spatial reasoning. The most relevant to typical 3D maps are basic measurements supporting typical uses of a map, such as tools for measuring different types of distances (straight line distance, horizontal distance, and distance over the ground) and angles in horizontal planes, as well as a true angle in space. The use of interactive tools to supplement 3D presentations overcomes the problems of distortion of dimensions and distances associated with perspective, where manual measurement is not possible (Pegg, 2013).

With the advent of GIS and geovisualisation, the role of maps has been redefined in recent decades to extend beyond the traditional understanding and to embrace their use as interfaces for GIS (Kraak and Ormeling, 2003; Ribarsky, 2005) and exploratory data analysis (Tukey, 1977; Andrienko and Andrienko, 1999). This application of 3D maps in GIS requires more advanced interactive tools and the extension of operations known from two-dimensional systems and of their underlying spatial relationship models, such as the 9-intersection model by Egenhofer and Franzosa (1991). Key requirements include support for the analysis of intersection, adjacency, connectivity, containment and disconnectedness (Ellul and Haklay, 2006).

However, due to the large volumes of data combined with the complexity of the required algorithms and data structures, development of spatial analysis tools seems to be slower than the progress that has been made in visual representations. Following an analysis of the leading commercial GIS systems available on the market undertaken by a team led by Zlatanova, it was concluded that all the systems reveal little provision of 3D GIS functionality in terms of 3D structuring, 3D manipulation and 3D analysis (Zlatanova et al., 2002b). Indeed, Musliman et al. (2006) called 3D GIS systems not much more than just “pretty models.”

Exploratory data analysis, enabled by interactive techniques, is based on a variety of tools which allow more advanced interaction with the data than simply controlling the view. These include tools based on techniques from statistical graphics such as dynamic classification, filtering, brushing and focusing (Andrienko et al., 2002; Crampton, 2002). Such elaborate methods of interaction are not used with popular maps but are rather reserved for professional data analysis of specific types of map, such as choropleth maps (Dykes, 1997). So what of the future of exploratory analysis? According to Rauschert et al. (2002), it lies in multi-modal interfaces, including not only mouse actions but also, possibly, voice commands and gestures. MacEachren (2005) believed that, particularly in the realm of visual analytics, the greatest insight would come from the combined efforts of many analysts working in collaboration. Theoretical and empirical examinations of the influence of the globalization of visualization may also be necessary, however, to maximize the capabilities of interactive maps for spatial data exploration. With the Internet, the ability to carry out international collaboration with users from diverse cultural backgrounds will prove to be powerful, although it may be necessary to examine differences in social interaction and symbolic conventions so as to design representations and interactions to involve these diverse users (Marcus, 2001; Shen et al., 2006; Edsall, 2007).

3.4.4 Summary

In summary, software that aids multi-agency risk assessment and decision-making has emerged and will continue to emerge, given technological progress. This chapter has examined different tools and the significant roles that technology plays in disaster management systems. While some have specific functions, others are more generic and comprehensive in their functions within the disaster management system. Based on the gaps identified in this chapter from examining different tools in disaster management, it is evident that limitations exist with respect to the technology tools that ensure an adequate risk assessment for the planning phase, especially for multiple agencies and stakeholders. Therefore, there is a clear need for platforms that can bring together the diverse information which planners need in their efforts to enhance risk assessment and preparation (if risks, hazards and disasters are be to better managed and their impacts mitigated and reduced). Furthermore, visualisation and the layering of information have emerged as the key aspects of this need for an enhancing platform as evaluated in this chapter. Thus, this research aims to fully investigate this need, focusing on the GMLRF because of the gaps identified in this chapter. The next chapter provides a theoretical foundation for this research, with investigations into the Activity Theory, into Critical Thinking, models of team collaboration and into a theoretical framework for this study.

Chapter 4 - Related Theoretical Frameworks

4.1 Introduction

This chapter presents a brief review of a number of related conceptual and theoretical frameworks that are useful in understanding and supporting collaboration and which could form the basis for supporting multi-agency risk assessment activities in disaster management. Significant evidence has emerged through research on the importance of social science theoretical frameworks in understanding humans' interaction through their use of tools and artefacts and in dealing with real-world cases in their surroundings (Wenger, 1998; Loo and Lee, 2001; Reddy et al., 2003). The theories and models that will be analysed are the activity theory (Engeström, 2001), the critical thinking model (Fischer et al., 2009) and the team collaboration model (Patel et al., 2011). The team collaboration model will incorporate insights from the field of Human-Computer Interaction (HCI), Computer-Supported Collaborative Work (CSCW) and Information Systems (IS). This chapter analyses how these theories and models guide the researcher in identifying the requirements of a collaborative environment platform for risk assessment activities. Starting with the activity theory, these models will be analysed in turn and the elements that are relevant to this research will be extracted.

4.2 Description and Justification of the Activity Theory

Managing any form of incident that can cause disruption in society and threaten lives can be challenging (Alexander, 2005). The management of incidents such as emergencies or disasters involves the coordination and integration of all activities necessary in order to build, sustain and improve all capacity and capability to prepare for, protect against, respond to, and recover from, the impact of such incident (CCA, 2004; Alexander, 2005). This infers that, in order to effectively or better manage incidents, it is important to engage in a critical thinking process that enables good decisions to be made (Flin et al., 2008). According to Fagel (2011), it is not so much thinking, as being able to integrate and coordinate all necessary tasks, actions and activities, that will translate mitigation and planning into effective responses and recovery from any impact that an incident can cause. Thus, the nature of disaster or emergency management suggests that any theoretical underpinning and explanation ought to focus on the thinking process, on thinking preferences or on critical thinking that can translate decisions into effective actions (Flin et al., 2008). There is also an emphasis on the importance of coordination and collaboration especially since the process involves different stakeholders and communication processes (Faraj and Xiao, 2006). The context and requirements for emergency and disaster management, therefore, stresses the relevance of theories such as the activity theory which is key for achieving goals (Jonassen and Rohrer-Murphy, 1999). The vertical and horizontal manner of coordination and integration required for effective emergency management (Bullock, 2006) also justify the relevance of the activity theory and the collaborative model. While these theories are relevant, this section further justifies their selection for critical review and for application to this research area.

The cultural historical theory (CHT) of activity was introduced by a group of Russian psychologists in the 1970s and 1980s determined to find a new approach to understanding and transforming human life (Vygotsky, 1978; Leont'ev, 1978; Raeithel, 1992). Vygotsky's main idea was to find human "cultural-historical science" with the aim of providing a unified account of "the nature and development of human behaviour" (Lantolf, 2006). The idea was to find a key for understanding human practices such as learning and doing and for developmental, cultural, historical and environmental contexts (Schatzki, 1996; Wenger, 1998; Stetsenko and Arievitch, 2004). However, the notion of activity in Soviet psychology (Wertsch, 1979) derives from the Marxist-Leninist tradition of dialectical historical materialism with its roots in the German classical philosophical tradition of Kant and Hegel. The main concept of the Marxist-Leninist tradition, upon which the philosophy of the activity theory is based, is the Marxist understanding of mind and consciousness, as these cannot be separated from the physical conditions of human existence (Marx and Engels, 1970).

The cultural historical theory supports a helpful analytical framework to assess the activities and artefacts that can be useful in a disaster management collaboration system (Bharosa et al., 2012). Robbins (2006) identified "theory" or "metatheory" as a philosophical framework exploring the "development of human culture and individual personality based on dialectical materialism". The purpose of CHT is to understand the structural subtleties that arrange people's historically-developed traditions of actions in conducting their tasks inside a work environment (in relation to available tools and technologies) and in producing services that meet the needs of a group of people (Chaiklin, 2011). Furthermore, CHT has the ability to explore the relationship between activity and context and can also interpret work practices as the social distribution of an individual's and a group of people's actions (Engeström, 1987). As a result, Chaiklin

(2011) stated that CHT is the basic unit of analysis in the activity theory of an individual’s and a group of people’s actions over a period of time.

An activity system seeks to describe the basic principles of CHT to understand the unity of realization (the human mind) and the activity (what we do) (Bannon and Bødker, 1991). Emphasis is placed throughout on human practices at the level of existing interactions of individuals acting in a purposeful social context (Chaiklin, 2007). It includes many notions relating to the capacity of the mind to refer to different kinds of objects such as history, mediation, collaboration, interpretation and development in constructing consciousness within, and out of, everyday practices (Nardi, 1996; Kaptelinin, 1996; Kuutti, 1996). However, the evolution of the activity theory which started from the works of Russian psychologists in the 1970s and 1980s, as explained earlier in this paragraph, provides the context and the influence on subsequent work and on the development of the theory. For instance, Engeström (2001) stated that the third generation activity theory is the appropriate method to study the mutual relationship between agencies where the activity systems of two or more agencies are collaborating. This argument shows an advancement upon the initial work by the Russian psychologists that merely sought to understand human life. While the initial work on the activity theory was fundamental to exploring the theory, the third generation activity theory indicated an advancement that is more specific to the relationship between entities for performing tasks.

The activity theory is a theoretical framework for the analysis and understanding of humans’ interaction through their use of tools and artefacts. Furthermore, the activity theory provides a general discovery method that can be used to support qualitative and interpretative research. It is also recommended for use in the processes of rapid and constant change within organizations (Hashim and Jones, 2007). The activity theory is significant as a framework for analysing how to achieve a goal, not only by using psychological and technical tools but also by utilising social structures such as rules, the division of labour and community (Jonassen & Rohrer-Murphy, 1999). Therefore, the activity theory provides a theoretical framework for exploring multi-agency collaboration which is the focus of this research.

Regardless of the critiques of some authors about the activity theory (critiques such as the nature of interactions required for achieving goals (Jonassen & Rohrer-Murphy, 1999)), (Bannon and Bødker, 1991), the activity theory has been used in a number of empirical studies with regard to the areas of human computer interaction (Korpela et al., 2002). This research focuses on studies of collaborative work in a diversity of fields and on examining the use of tools to help with this work. Furthermore, according to Korpela et al. (2002), the activity theory is used not only to study the work of system design but also can be used to look at the collaboration between a designer and a client with their different cultures, thoughts and experience. As identified by Engeström (1999, 2001), this type of unit is mainly used to gain benefit from expert work and in dealing with complex work such as education and healthcare in critical times in order to organize cross-boundary work that has different objects and cultures; it allows more emphasis to be placed on complex work in order to create or design methods, models and artefacts (Miettinen and Hasu, 2002).

Furthermore, the activity theory is a powerful descriptive tool that can be used in various disciplines (Nardi, 1996). It can explain phenomena as a set of factors, processes and techniques which can be used in investigations to find solutions for different complex problems (Kaptelinin et al., 1999; Korpela et al., 2000; Mwanza, 2001). Researchers use the activity theory as a framework that can support and determine user requirements for analysis or to support the evaluation phases of a scheme (Kaptelinin et al., 1999). In fields which, in general, incorporate approaches involving human activity (such as in psychology, education, management, culture and information systems), the activity theory has been an inspiration for theoretical reflection (Crawford & Hasan, 2006; Hakkinen & Korpela, 2006).

4.2.1 The First Generation: Vygotsky’s Foundation

According to Vygotsky's first generation of activity theory, focusing on individuals, tools are used to mediate between the subject and the object of an activity. The activity is completed in order to achieve a needed outcome. Vygotsky (1978) also indicated that the human mind is mediated by a third element, and humans can access the world only indirectly, or mediately, rather than directly, or immediately (Wertsch, del Rio & Alvarez, 1995). The notion of mediated activity as the unit of analysis has a deep influence on psychology as it means that the individual might no more be known without his or her cultural means; society might no more be known without the group of individuals who use and produce artefacts (Engeström, 2001). Cultural artefacts have mediated human consciousness which consists of voluntary attention, planning, problem solving, evaluation, conceptual thought, logical memory and learning (Cole & Engeström, 1993; Lantolf & Appel, 1994).

“The use of artificial means, the transition to mediated activity, fundamentally changes all psychological operations just as the use of tools limitlessly broadens the range of activities within which the new psychological functions may operate. In this context, we can use the term higher psychological function, or higher behaviour as referring to the combination of tool and sign in psychological activity” (Vygotsky, 1978).

Therefore, these cultural artefacts can be physical tools (for example, a computer or a mobile or a radio) that are outwardly oriented or symbolic tools (for example, strategies, arithmetics, language and signs) that are more inwardly oriented (Cole & Engeström, 1993). The symbolic tools’ role is to mediate human consciousness; therefore, humans might be able to exchange and improve their mental activities and performance (Lantolf and Appel, 1994). Humans still try to control nature by creating tools that will support them in collaborating with other people in order to achieve their goals (Lantolf and Appel, 1994).

4.2.2 The Second Generation: Leont’ev’s General Structure of Activity

The second generation of the activity theory as expanded by Engeström (1999) added the influence of social components within an activity. These social factors consist of community, rules and the division of labour (see Figure 2.1). Engeström’s model also described how the new social factors influence each other. In this model, community involves all subjects (i.e., individuals/organisations) sharing the same object. Figure 4. 1 below represents the theoretical framework that supports this study, and consists of the six interactive components in an activity system: subject, object, tools, rules, community and division of labour. The subject can be one person or a group of people who share the same object and subjects can be involved in a variety of activities, each with different objects, forming many different activity systems. With the subjects’ activities directed towards the object (goal), the objects of various subjects involved in a process should overlap or be shared to some extent in order to achieve a common outcome. Tools are the artefacts that are used by the subjects to carry out the activity in order to achieve an object, and may be physical tools such as pen and paper and computer software; they can also be cognitive properties such as language and methods of communicating. Rules refer to the explicit or implicit routines, policies and guidelines that determine and govern the activity within the community. Division of labour refers to how the tasks and work are divided among members of the community (i.e., all subjects who espouse similar values, beliefs and rituals in an activity). Rules mediate subjects and the community and influence how the community functions as a whole, while division of labour dictates how the community functions towards the shared object (Engeström, 2000).

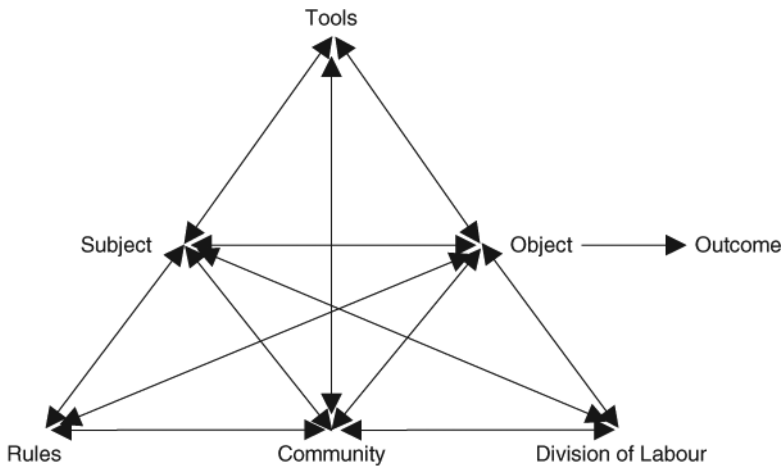


Figure 4. 1: The Activity Theory (Engeström, 2001).

A general structure of activity, as indicated by Kuutti (1996), shows three hierarchies, activity, action and operation, which can be individuals or groups. Also there are corresponding terms; these are motive, goal and conditions. According to Leont'ev (1981), activities consist of actions or chains of actions and these actions consist of operations. This hierarchy is illustrated in Figure 4. 2 Kuutti (1996) explained these levels by defining the activity (motive) of "building a house", the action level of "fixing the roof, transporting bricks by truck" and the operation level as "hammering, changing gears when driving".

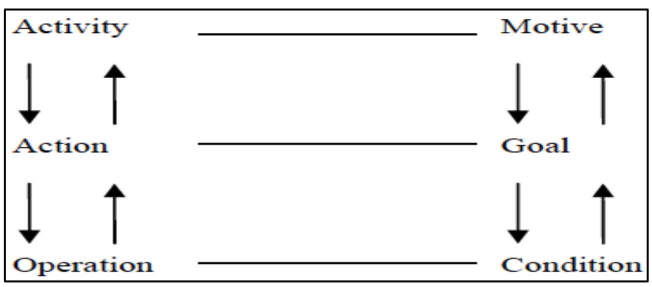


Figure 4. 2: The three levels of activity (Leont'ev, 1981).

These abstract concepts are also illustrated by Leont'ev (1981) as 'hunters searching for food'. Specifically, it is the overall need to find food for the group which motivates the activity, although each individual member of the group performs specific actions in order to realise this need. The hunter who beats a drum to scare animals towards other hunters (action), when taken in isolation, may appear to have no connection to the need to obtain food; when seen as a step in a wider activity, however, its meaning is clear. In turn, actions are composed of operations, such as walking or beating the drum, and these operations are shaped by conditions, such as the making of the drum and drumstick or the nature of the physical surroundings and climate (Barab et al., 2004). Leont'ev, therefore, illustrates the difference between individual and collective actions and their relation to one another (Engeström, 2001).

4.2.3 The Third Generation – Interacting Activity Systems as the New Unit of Analysis

The third generation of the activity theory, commonly known as the cultural historical activity theory (CHAT), is an appropriate method for inter-organization analysis when the activity systems of two or more agencies are interacting. Additionally, it has the ability to expand the unit of analysis from one activity system to at least two interacting activity systems as the minimal unit of analysis (Engeström, 2001). The reason that it is useful for multi-agencies to use this theory is that among multi-agencies it is essential to analyse interaction and model each activity system individually (Engeström, 2001). The concept of boundary crossing is being developed within the activity theory (Engeström et al., 1995), for example, it has been used in the area of education to test connections between work and universities (Finlay, 2008). Consequently, the new unit of analysis expands from one activity system to "two or more collaborating activity systems that are embedded in a social, cultural and historical process" (Tuomi-Gröhn et al., 2003). Therefore, the third generation of activity theory could provide a crucial solution to expanding the inside working of individual in an activity system to two or more activity systems between agencies involved in disaster management (see Figure 4. 3).

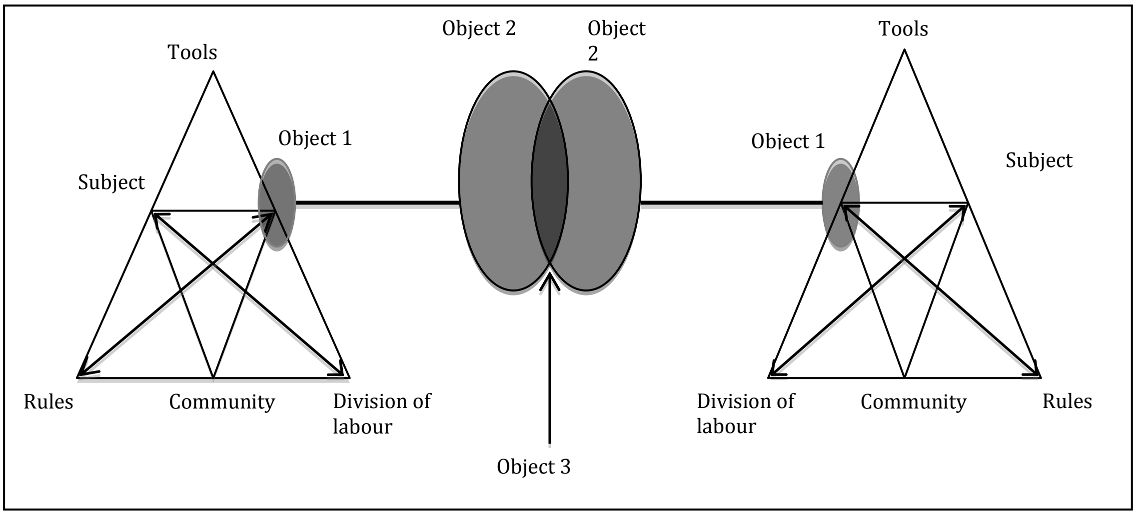


Figure 4. 3: The third generation of activity theory (Engeström, 2001)

The activity theory may be summarized with the help of five principles (Engeström, 1993, 1995, 1999):

1. A collective, artefact mediated, object-oriented activity system, in its network relations to other activity systems, is the prime unit of analysis.

2. An activity system is a multi-voiced community with different viewpoints, histories and interests, which is multiplied in the networks of activity systems. Engeström noted the division of labour as being one source of these differences. This principle is "a source of trouble and a source of innovation, demanding actions of translation and innovation" (Engeström, 1993, 1995, 1999).

3. The principle of historicity: activity systems evolve and develop over lengthy periods of time and researchers must understand this via the systems' relationship to the development of objects, tools and culture, etc.

4. Contradictions are the source of change and development. In the case of multiple interacting activity systems, contradictions are manifest both within and between activity systems.

5. The principle of the possibility of expansive transformations in activity systems. Activity systems move through relatively long cycles of qualitative transformations. An expansive transformation is accomplished when the object and motive of the activity are reconceptualized in order to embrace a radically wider horizon of possibilities than in the previous mode of the activity.

4.2.4 Contradictions within Activity Systems

Contradictions are basic elements of activity systems that are reflected as conflicts, problems, tensions or collapses inside the activity system or among different systems (Kuutti, 1996). In fact, there are many stress points and stable activity systems are rare: "tensions, disturbances, and local innovations are the rule and the engine of change" (Cole & Engeström, 1993). Thus, contradictions should not be taken as being negative but as difficulties that need to be resolved which serve as a guide to the transformation of activity (Issroff & Scanlon, 2002). Contradictions can be at different levels of the activity system and in each node (element) of the activity system; for instance, tensions inside subjects, among nodes, between the community and the division of labour, or between diverse activity systems such as the fire service and the police service (Barab et al., 2004). Contradiction can develop between nodes when a new tool is introduced into a community that has no understanding of how to use it yet. Engeström (1997) defines four sources of contradictions which are summarised in Table 4. 1.

Table 4. 1: Summary of levels of contradiction in activity systems (Engeström, 1997)

Level	Description	Example
Primary	Inner contradiction within each constituent component of the central activity. The tensions found within an element of a single activity.	Doctors working in a health care system where the instruments of their activity (drugs, etc.) answer the needs of patients (use value), but are also commodities that have to be provided within a budget (exchange value).
Secondary	Appearing between the nodes of the triangle – where there is a mismatch between the actual and the required level of development of one of the nodes, and the relationship between them breaks down. Those found between two elements of a single activity.	Mismatches between the conceptual diagnostic tools of traditional medical practice and the object – the increasingly ambiguous and evolving complaints of patients.
Tertiary	Appears when a more "culturally advanced" form of the object/motive of activity is introduced into the system which needs to develop to support it.	New procedures or values introduced by administrators or governors which are formally introduced, but

	The imbalances found between an activity and a culturally more advanced version of this same activity (co-constructed with the stakeholders).	which may be resisted by practitioners.
Quaternary	Contradictions between the central activity system being studied and its neighbouring activity systems. The tensions between different activities.	Differences between doctors and patients, or between local and centralised healthcare providers in their approach to the object of activity.

Primary contradictions can be understood in terms of a breakdown between actions or sets of actions that realise the activity. Such actions are poly-motivated which means that the same action may be executed by different people for different reasons or by the same person as part of two separate activities. Poly-motivation may be the cause of subsequent contradictions. Secondary contradictions are those that occur between the constituent nodes, eg, between the subject's skills and the tool he/she is using, or between rules and tools. Tertiary contradiction occurs between an existing activity and a more advanced form of that activity, such as when an activity is remodelled to take into account new motives or new ways of working. Quaternary contradictions are those between the central and neighbouring activities, e.g. instrument producing, subject-producing and rule producing. A more detailed explanation of the meaning of activity tension and contradictions is illustrated in Figure 4. 4.

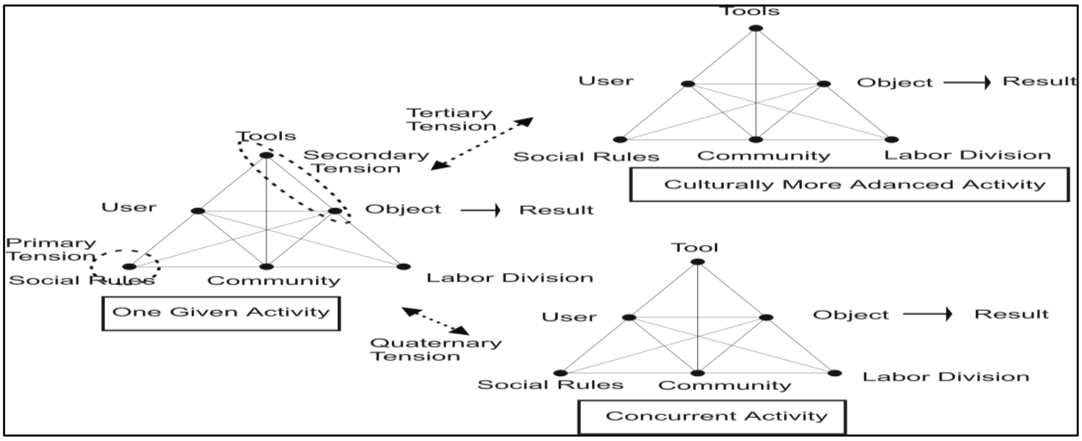


Figure 4. 4: Activity tension and contradiction (Engeström, 1987)

4.2.5 Adaptation of the Activity Theory for Multi-agency Collaboration

According to Mishra et al. (2011a), the activity theory has been shown to be a valuable tool for analysing information sharing among multi-agencies involved in risk assessment in disaster management. The activity theory also described by Mishra et al. (2011b) as a powerful methodological and analytical tool to study the information practices of the emergency services. Given that the activity theory provides a way to model and understand the actions of groups in pursuit of common goals (especially when the transfer of information is important to their efforts) then it seems that the third generation activity theory (Engeström, 2001), in particular, provides a strong analytical framework to analyse multi-agency activities. This version of the activity theory is suitable when studying inter-organizational activity systems, whereby two or more agencies are interacting. The theory stresses the importance of collaboration between members of multi-agency groups. The work of the Greater Manchester Local Resilience Forum members can be analysed from an activity theory perspective. This is illustrated in table 4.2, figure 4.5 and figure 4.6 shows example of multiple activity models.

Table 4. 2: Description of the nodes within an activity system

Nodes	**Description**
Subject	Representatives of category 1 responders in The Greater Manchester Local Resilience Forum such as Commander of the police, ambulance service, NHS, local authority, Environment Agency, fire service and rescue and transport agency.
Object	In this case, it is the completion of risk assessment activities and the understanding of local risks.
Outcome	Confidence in disaster resilience and preparedness.
Tools	Tools for the visualization of the local risk context. (Social vulnerability, critical infrastructure, hazards' sites, natural sites, etc.).
Rules	Comprehensive approaches to Disaster Management, Integrated Emergency Management (IEM) and risk assessment processes that are carried out by multi-agency teams in the Greater Manchester LRF.
Community	The Greater Manchester Local Resilience Forum comprising Category 1 & 2 responders.
Division of Labour	The task allocation for each individual in the system; how tasks are split horizontally between community members; the clarified responsibilities of each team member.

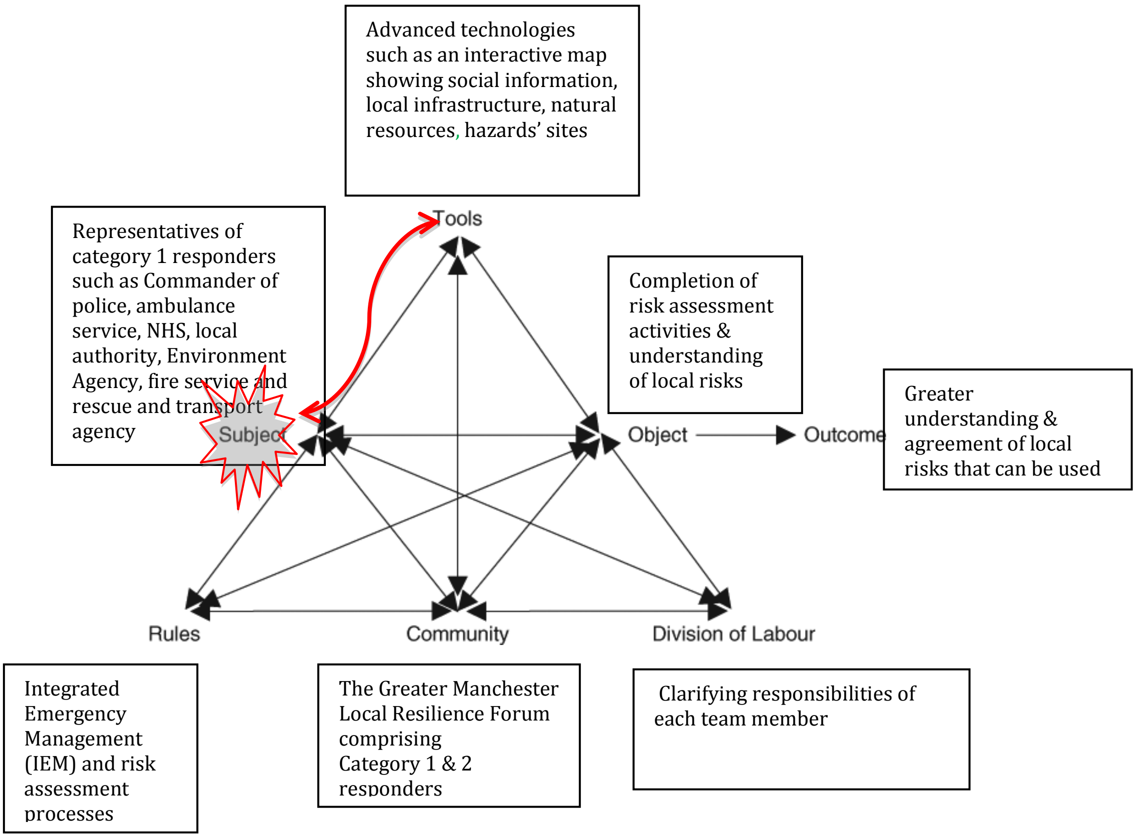


Figure 4. 5: Activity model for the senior commanders of agencies looking at risk assessment

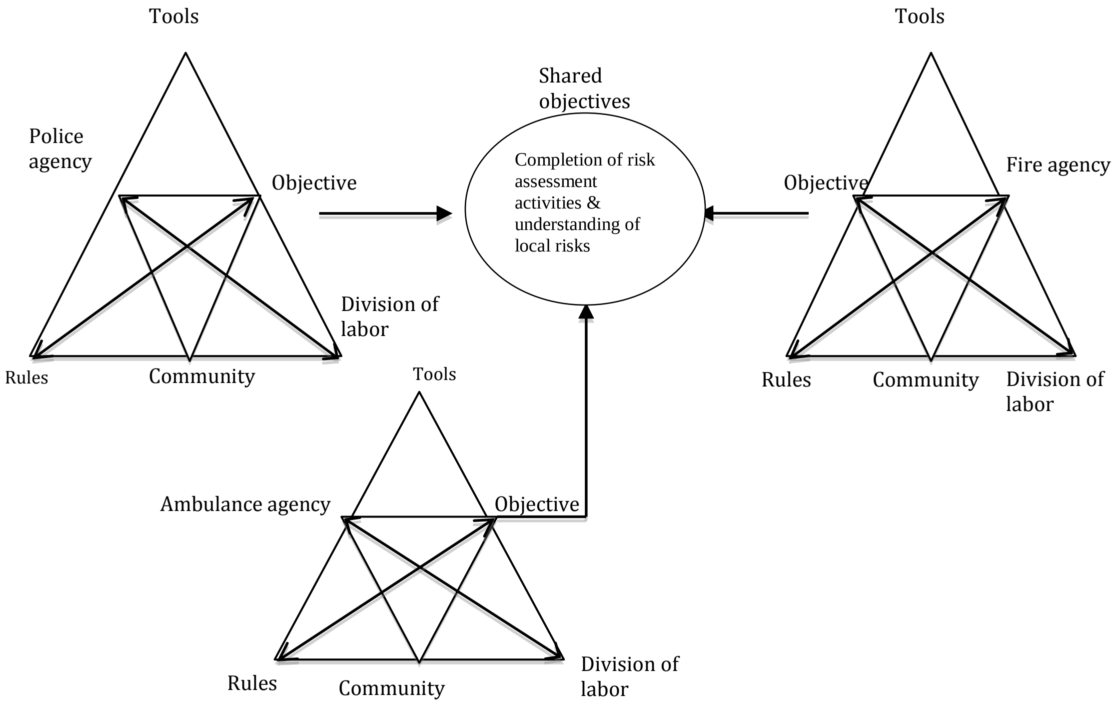


Figure 4. 6: Example of multiple activity models for the senior commanders of agencies looking at risk assessment.

The activity theory provides an important framework for understanding the collaboration between multi-agencies in risk assessment research. The activity theory highlights the need to understand the interaction between the members of multi-agency teams in general by analysing subjects, object, rules, tools and community.

Numerous elements of the activity theory were looked at during the literature review. Firstly, there is the community aspect. In this case, the community is made up of Category 1 & 2 responders in The Greater Manchester Local Resilience Forum in England. Within this community, the activity theory provides a way of defining the subjects who need to be targeted for the collection of primary data; in this case, the commanders of Category 1 agencies (such as the Greater Manchester Police service, the Greater Manchester Fire and Rescue service, the National Health Service, the NW Ambulance Service, the Greater Manchester Local Authority, the Environment Agency, Transportation for Greater Manchester and representatives from the UK's central government). Furthermore, the activity theory suggests that the division of labour between these subjects is important, so the literature review aims to identify their roles and responsibilities.

Another aspect of the activity theory that guides this research is the rules that are followed in the UK for a comprehensive approach to disaster management which, in this case, are known as Integrated Emergency Management. Of specific importance are the risk assessment processes that are carried out by the multi-agency teams in the Greater Manchester LRF to understand local risks. The understanding of local risk is the common objective of the stakeholders involved. Therefore, the activity theory has also guided the identification of the research problem and the research questions because, without knowing the common objectives of the stakeholders, there is no way of fully understanding their activities. This has guided the literature review which looked to identify the problems and challenges faced by multi-agency teams in meeting their common objectives.

Tools are another element of the activity theory which has guided the literature review to investigate the technological platforms currently available and which are applied in the collaboration, communication and information sharing between agencies in general and in the Greater Manchester LRF in particular. Moreover, the activity theory helps to guide the development of tools that are successful in supporting multi-agency teams in collectively understanding their context and in sharing information about their local area.

As previously noted, the activity theory underscores the importance of collaboration in the activities of the Greater Manchester LRF. As the LRF is made up of representatives of different agencies, each with access to their own knowledge and experience, then the sharing of information between these agencies is vital in order to support collaboration. Therefore, this research focuses on the sharing of information, on the technology platforms that allow this sharing and on the stakeholders who have this information and access this information in order to meet their common objectives.

As a result, from an activity theory perspective, this research focuses on subjects and tools. Of particular importance and interest to this research is the activity theory's concept of contradiction. As previously described, contradictions result from the problems, tensions and gaps at different levels within an activity system. Professionals engaged in collaborative risk assessment face numerous problems in their work. For instance, professionals might lack good communication within their team, which in the activity theory would be a primary contradiction. Similarly, team members might be unable to correctly use the technological tools at their disposal in order to assess risk or they may not be fully able to read and understand the data presented to them in a visual way. These are examples of secondary contradictions in the activity theory. In terms of the activity theory, this research is aimed at resolving some of the contradictions relating specifically to the communication and sharing of information between members of multi-agency teams and the contradictions relating to their interaction with their tools (technology platforms).

Overall, an analysis of the activity theory provides a strong influence on this research, including the collection of secondary data in the literature review, defining the research questions and in highlighting the importance of collaboration in the activities of the Greater Manchester LRF.

4.3 Critical Thinking in Disaster Management

According to Sagun et al. (2009), because of the evolving and uncertain nature of the risks of hazards due to human interference, the information available to emergency managers can be unreliable and inconsistent. This makes critical thinking crucial within the disaster management processes, including disaster risk management. As a result, research into critical thinking skills is important in order to support strategic commanders in their risk assessment activities (Moore et al., 2007). Critical thinking is essential for managers in risk assessment. This type of thinking is required in the planning and preparedness phase (Alexander, 2005). CT is needed in order to be able to deal with the massive data received in order to determine the relevant ones to prioritise for the risk assessment process (Fagel, 2011). Furthermore, inferences need to be made for comparison, for information analysis and for coordination and collaboration between stakeholders for risk management actions (Faraj and Xiao, 2006). The emergency managers design the plan which means that they have to be aware of all the needs to meet and of how suitable the plan is for the context to which it will be applied.

Critical thinking (CT) has become an important area in various disciplines in the last twenty years. Professionals in areas such as military leadership, healthcare, education and emergency management have seen the importance of CT grow (e.g., Cohen et al, 1994; Fallesen et al, 1996; Miller & Malcolm, 1990; National Education Goals Panel, 1991; Tucker, 1996; Comfort, 2007).

As indicated by Haddow et al. (2008), emergency management starts at the local level. The professionals at the local level are essential in the creation of collaborative emergency mitigation, preparedness, response and recovery (Col, 2007; Henstra, 2010; Waugh & Streib, 2006). Local emergency managers have to identify risks and manage vulnerable people and communities. This involves taking into account a complex range of factors such as critical infrastructure, population and the socio-economic makeup of the community. Moreover, Wang and Kapucu (2008) noted that when local emergency managers create their strategic plans they must create and use different methods to communicate threats and warnings to the public before and during disasters. They noted that critical thinking skills must be employed at the preparedness and strategic planning stage. In short, critical thinking is crucial to the work of local government emergency managers (Perry, 2003) in their work in identifying and anticipating incidents, solving problems and making effective decisions in an efficient way (Comfort, 2007). The cognitive processes that go into critical thinking have been identified as being the basis for emergency management by Comfort (2007). Due to the importance of CT skills, this is a growing area of interest for researchers.

4.3.1 Literature Review on Critical Thinking

Critical thinking can be understood as a process that involves two different modes of thought. Bloom (1956) wrote extensively on modes of thinking that can be used to introduce the underlying idea of critical thinking. In Bloom's model (1956), the cognitive domain of reasoning relates to knowledge and intellect. Bloom's model divides the cognitive domain into six areas: knowledge and recollection of information, identifying and understanding problems, applying existing concepts to new demands, analysis of information, forming patterns and evaluating ideas and making judgments about the value of ideas (Bloom, 1956).

Bloom's model also involves an affective domain. In contrast to the cognitive domain, which relates to ideas and facts, the affective domain relates to other areas such as emotions, attitudes and motivations. Bloom's model has been very influential on educators in a range of disciplines and has led to a growing interest in critical thinking, which effectively brings together the cognitive and affective domains that Bloom identified.

There are a number of different definitions for critical thinking expressed by a number of scholars. For instance, Tama (1989) described it as 'a way of reasoning that demands adequate support for one's beliefs and an unwillingness to be persuaded unless support is forthcoming'. Chance (1986) defined it as 'the ability to analyse facts, generate and organize ideas, defend opinions, make comparisons, draw inferences, evaluate arguments and solve problems'. Mayer and Goodchild (1990) outlined it as the 'active, systematic process of understanding and evaluating arguments. An argument provides an assertion about the properties of some object or the relationship between two or more objects and evidence to support or refute the assertion. Critical thinkers acknowledge that there is no single correct way to understand and evaluate arguments and that all attempts are not necessarily successful'. Common to each of these definitions is the notion that critical thinking relates to the critical evaluation of ideas and the subjection of ideas to reason. The most comprehensive and commonly used definition comes from The National Council for Excellence in Critical Thinking which draws upon the work of hundreds of writers and researchers. Its definition of critical thinking is: 'the intellectually disciplined process of actively and skilfully conceptualizing, applying, analysing, synthesizing, or evaluating information gathered from or generated by, observation, experience, reflection, reasoning or communication, as a guide to belief and action' (National Council for Excellence in Critical Thinking, 2008, 1).

In addition to these definitions, scholars have proposed models to describe critical thinking. Brookfield (1987) identified four elements of critical thinking. These are assumptions, context, alternatives and reflective scepticism.

Assumptions: Brookfield describes the challenging and testing of assumptions as an important element of critical thinking. In his analysis, critical thinkers are mindful of how their existing assumptions about the nature of the world might influence their perceptions, explanations and judgments of different phenomena.

Context: Closely linked to assumptions, critical thinking involves the awareness of how underlying assumptions provide the context for a person's thinking.

Alternatives: Brookfield suggests that thinking with creativity and imagination is a foundation of critical thinking. He suggests that critical thinking always looks for alternative ways to look at problems.

Scepticism: Brookfield's view is that critical thinkers approach their own beliefs and ideas with scepticism and are constantly testing and refining them, without taking seemingly obvious ideas for granted.

Paul and Elder (2005) developed Brookfield's model into a more detailed taxonomy of critical thinking. They organized it into eight elements of thought that follow on from each other. They described critical thinking as a person's ability to find important and worthwhile questions and problems, to find and evaluate information that is relevant to these questions or problems and then to use abstract ideas to interpret this information and arrive at rational, reasonable conclusions. These conclusions are then subjected to evaluation against relevant criteria or standards. Moreover, critical thinking involves constant recognition of biases, openness to alternative ideas and an understanding of the implications of an idea. In short, the process of critical thinking starts with the identification of a problem and develops a workable solution based on reason.

While Brookfield's model is a general description of critical thinking, Paul and Elder's model provides a formalized procedure to follow which can be applied to many situations and disciplines. It forms a checklist of activities to follow and explicit questions to ask that are related to each element of the process. This is shown below in Table 4. 3.

Table 4. 3: Scientific thinking (Paul and Elder, 2005)

The Elements of Scientific Thought	A Checklist for Scientific Reasoning	Questions Using the Elements of Scientific Thought
Scientific Purpose	• Take time to state your purpose clearly. • Distinguish your purpose from related purposes. • Check periodically to be sure you are still on target. • Choose realistic scientific purposes.	• What am I trying to accomplish? • What is my central aim? My purpose?
Scientific Questions	• Take time to clearly and precisely state the question at issue. • Express the question in several ways to clarify its meaning and scope. • Break the question into sub-questions. • Determine if the question has one right answer, or requires reasoning from more than one hypothesis or point of view.	• What question am I raising? • What problem am I addressing?
Scientific Information	• Restrict your claims to those supported by the data you have. • Search for data that opposes your position as well as alternative theories. • Make sure that all data used is clear, accurate,	• What data am I using in coming to that conclusion? • What information do I need to settle the question?

	and relevant to the question at issue. • Make sure you have gathered sufficient data.	
Scientific Inferences/ Conclusions	• Infer only what the data implies. • Check inferences for their consistency with each other. • Identify assumptions which led you to your conclusions.	• How did I reach this conclusion? • Is there another way to interpret the information?
Scientific Concepts	• Identify key scientific concepts and explain them clearly. • Consider alternative concepts or alternative definitions of concepts. • Make sure you are using concepts and theories with care and precision.	• What is the main concept, theory, or principle here? • Can I explain the relevant theory?
Assumptions	• Clearly identify your assumptions and determine whether they are justifiable. • Consider how your assumptions are shaping your point of view.	• What am I taking for granted? • What assumption has led me to that conclusion?
Implications/Consequences	• Trace the implications and consequences that follow from your data and reasoning. • Search for negative as well as positive implications. • Consider all possible implications.	• What are the implications of the data I have collected? • What are the implications of my inferences?
Points of View	• Identify your point of view. Make sure it is scientific. • Seek other scientific points of view and identify their strengths as well as weaknesses.	• From what point of view am I looking at this issue? • Is there another point of view I should consider?

Fischer et al. (2009) proposed another model of critical thinking. Their model was developed with military decision makers in mind and brings together a great deal of previous literature on the subject of critical thinking. Although it draws on previous work on the subject, the model departs considerably from previous models in a number of ways. Firstly, the model is concerned with describing the cognitive processes that occur in people who are thinking critically, rather than prescribing useful procedures for them to follow. Also, the goals of the model are fundamentally different. While many models of critical thinking aim to give individuals a set of techniques to use, this model views critical thinking as a psychological event.

The model looks to describe what goes on inside the mind of a critical thinker during periods of critical thinking. These periods are assumed to be quite short, ranging from 5 to 30 minutes. In the model, critical thinking is viewed and explained as a state of mind that begins and ends depending on the situation. Moreover, this model suggests that critical thinking involves small units of information which have an effect on the thinker. The authors suggest that, while other models might involve a stimulus like a book or report, their own model assumes that a stimulus is a much smaller unit of information such as a photograph or a sentence. In summary, most models of critical thinking describe it as a way of life, while this model describes it as a temporary state of mind.

Finally, and most relevant to this research, this model departs from others in that it gives practical considerations for the provision of stimuli. The writers suggest that because small units of information bring on critical thinking, then this information can be manipulated and structured to encourage and influence critical thinking, as shown in Figure 4. 7.

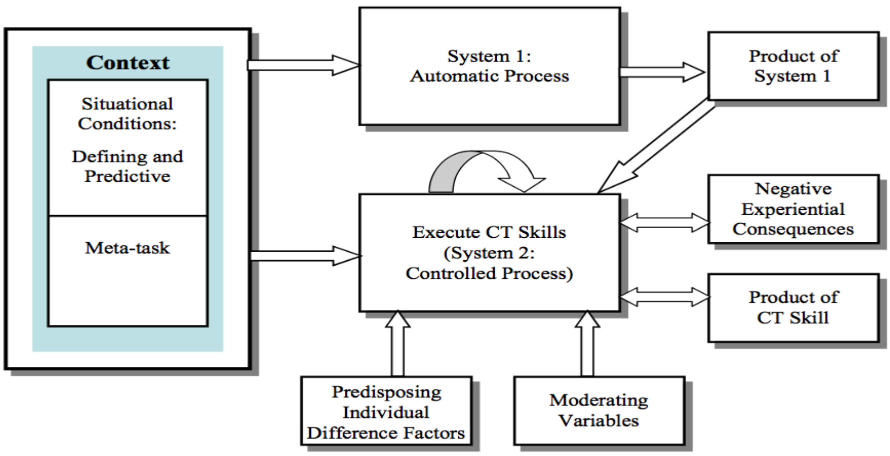


Figure 4. 7: Process model of critical thinking (Fischer et al., 2009)

The model begins with a context that produces a period of critical thinking. This context is an event or piece of information in the external environment which starts the psychological process in the mind of the critical thinker. To produce critical thinking, a situation must involve the introduction of important information that is of interest to the thinker and time must be available for the thinker to process it. These are the "defining conditions" of critical thinking. Other factors that might lead to critical thinking include the presence of information that is complex or uncertain. These factors are referred to as "predictive' conditions in the model. To summarise, this context is an event that stimulates two related mental processes.

The first process is automatic and unconscious, similar to the assumptions that were identified in Brookfield's model. This is labelled as System 1 in the model. This system influences System 2 which is conscious and deliberate in the mind of the thinker. System 2 begins with a "meta-task" which is the objective that a thinker has to achieve. This could be something to understand, a judgement to make, a decision to make or a problem to solve. This meta-task governs the critical thinking that follows in System 2.

System 2 is the overall act of critical thinking. It is influenced by a series of factors shown with arrows in Figure 2.6. These include the unconscious beliefs from System 1 and a range of other factors. The first two factors are "Predisposing Individual Difference Factors" and "Moderating Variables". These are both individual differences that differ from thinker to thinker. Predisposing Individual Differences affect the likelihood of critical thinking taking place. They relate to the thinker's personality, values and style of thinking. Examples include a thinker's "open mindedness", "confidence" and "adaptability".

By contrast, Moderating Variables influence the quality of the critical thinking that takes place. Rather than the personality of the thinker, they relate to the thinker's situation. For example, the education, recent experience, alertness and health of the thinker could all affect how well they critically think.

In addition, "Negative Experiential Consequences" also influence the execution of critical thinking. This relates to how difficult and demanding a period of CT is for the thinker. The creators of this model suggest that CT is hard work, leading to negative effects for the thinker such as tiredness, anxiety and social awkwardness. The greater the negative effects, the worse the experience of critical thinking is for the thinker and the greater the potential negative effect on the process of critical thinking itself. Furthermore, the negative effects of one experience of critical thinking could negatively impact on future situations of critical thinking and, therefore, the decisions produced in them.

Finally, the model provides an outcome of critical thinking, referred to as the "Product of CT Skill". This is, in effect, the final decision made after a period of critical thinking or, in other words, the solution to the meta-task.

Fischer et al.'s model has a number of advantages over its counterparts and is particularly useful in the context of this research. Firstly, the model has produced predictions that have been empirically tested. As a result, the model has been adopted as part of American military training courses. This demonstrates how useful the model has been in a practical context that is similar to emergency management.

More generally, the model is useful to this research because it does not only focus on the people engaged in critical thinking. In fact, it offers guidance for the designers of the information that these people are given. Furthermore, by describing the negative effects of critical thinking, such as tiredness, anxiety and social awkwardness, the model reflects the goal of this research which is how best to create a collaborative risk assessment environment in emergency management. The model shows that a collaborative platform should reduce negative effects and promote the effective critical thinking that is so important for emergency management professionals. The model suggests that an effective platform should free up users' attention. If, for example, information is visualized, then users do not have to spend mental effort on imagining a scenario. They can, therefore, spend more mental effort on critical thinking. This is an example of how a platform could reduce negative effects and promote critical thinking during users' strategic planning.

Moreover, Fischer et al. (2009) outlined the critical thinking skills that each individual possesses to a greater or lesser extent. These include interpretation skills such as the ability to retrieve the gist of material, to break overall goals into smaller sub-goals, to question a matter deeply and to identify and challenge previously held assumptions. Reasoning skills, which are included in the critical thinking model, are a person's ability to think logically, to apply general principles to specific cases and to determine if the evidence available is enough to justify conclusions. The assessment skills included in critical thinking skills include the ability to understand new information (and know how it supports or contradicts conclusions), to consider new evidence that becomes available, to balance a variety of different factors when needed and to evaluate the quality of judgments based on patterns. Finally, the meta-cognitive skills within critical thinking skills include a person's capacity to take into consideration a number of alternative explanations, to produce multiple ideas and to account for a whole situation when making decisions.

These critical thinking skills are crucial for multi-agency collaboration because this collaboration involves evidence-based decision-making and strategic planning. Therefore, the design of a platform to enhance collaboration needs to take these skills into account. Moreover, these skills will provide a way of evaluating the success of a prototype in enhancing critical thinking among multi-agency team members in their risk assessment activities.

4.4 Team Collaboration Model

Several models of good practice for team collaboration have been put forward from various disciplines. For instance, Kusumasari et al. (2011) have developed a model of collaboration in the field of software development, as shown in Figure 4. 8. This model defines a cycle of 5 stages for team collaboration. These stages begin with communication with stakeholders or clients (as this model comes from the field of software design), followed by a planning stage. The plans that have been created are then modelled and then put into practice in the construction stage. The constructed project is then released in the deployment stage. The cycle is completed when communication once again takes place between the designers and the stakeholders or clients, gaining feedback on the project. Underlying this cycle is the need for face-to-face and electronic communication between team members and the use of collaborative tools so that they can work on together to achieve their goal.

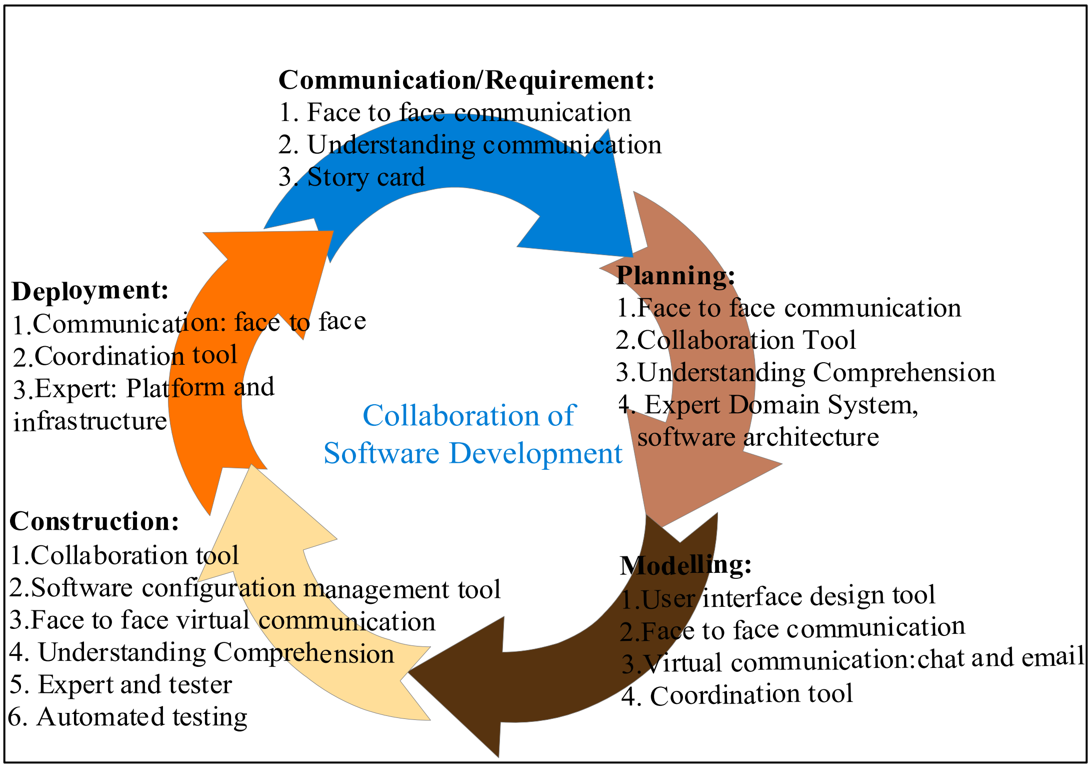


Figure 4. 8: Collaboration model of software development (Kusumasari et al., 2011)

While the Kusumasari et al. model essentially focuses on the kinds of communication required in each stage of collaboration and the tools that can be used to support this communication, other models of collaboration have looked at from a different perspective. Warner et al. (2005) outlined a cognitive model of team collaboration which focuses particularly on the processes of reasoning and decision-making amongst teams. The model starts with a series of inputs that contextualize the collaboration such as a description of the problem, the experience and skills of the team members, the structure of the team and the team members' roles and responsibilities. Aside from these inputs, the model then outlines four connected but separate stages of team collaboration which form a feedback cycle. The stages are knowledge construction, collaborative team problem-solving, team consensus and outcome and, finally, evaluation and revision. The model emphasizes the constant dynamic communication that is required throughout the process.

A well-known model of collaboration which has been tested empirically is the one put forward by Patel et al. (2012). They proposed the Co-spaces Collaborative Working Model (CCWM) which describes the factors that affect collaborative work. The CCWM is now a recognized model of collaboration in a number of disciplines including academic, industrial and ICT circles (Patel et al., 2012; Lee & Paine, 2015). Moreover, research in the field of medicine has shown that the model can be applied in that field too. Overall, in focusing on human factors affecting collaboration, the CCWM provides a useful standard for collaboration in many fields (Patel et al., 2012). The model identifies the following categories for these factors: context, support, tasks, processes, teams, individuals and overarching factors.

Context is the setting for collaborative work, such as its physical location, the organizations involved and the individuals involved. Support relates to the assistance, resources and tools available to a team as well as the team's ability to get advice and expertise from outside. Tasks are the activities that teams must undertake and they can be analysed according to the type of task (for example, routine, predictable, complex) but also by task structure. Interaction processes are the ways in which the members of a group interact (e.g., in the areas of learning, coordination, communication and decision-making). CCWM also includes a team category which consists of the roles and responsibilities of team members, the sharing of knowledge, the common ground held by team members, the procedures a group follows and the composition of the team. In the model's individual category are the skills of the individual team members. These skills can be technical but cognitive, such as reasoning skills, the ability to perceive and process information, the capacity for concentration and learning style. The final category in the model is overarching factors which influence all the previously mentioned categories. An example of an overarching factor is trust between, and within, teams.

In order to explore the multi-agency collaboration needed in risk assessment activities in LRFs in England, this research will further investigate the human factors involved in these activities, including interaction processes, individuals, teams and tasks. These factors are important in the context of this research because interaction processes relate both to the interaction between team members and to the interaction between users and their technological tools, such as the interactive map. Teams and individuals are also relevant in this research because this research focuses on teams made up of individuals from multiple agencies. Therefore, there needs to be collaboration between the individuals who are part of the LRF team and also between the agencies that represented in the LRF. Finally, tasks are important to this research because this research needs to understand the tasks faced by multi–agency team members so it can enhance the interaction and communication needed. Computer Supported Collaborative Working (CSCW) provides a way of applying computers to enhance collaboration. CSCW is a multi-disciplinary approach to the tools that support and enhance groups of people working together. Since its inception in the 1980s, it has been conceptualized and revised by numerous writers such as Howard (1988), Kling (1991) and Clement & van Besselaar (1993). However, at the centre of CSCW is the study of the reality of human collaboration and how computer tools should be developed in light of this, in order to enhance and promote collaboration (Koschmann et al., 1996). To best understand how multi-agency activities are conducted (and, therefore, how they can be supported and enhanced), it is valuable to look at the model of multi-user interfaces developed by Miles et al. (1993).

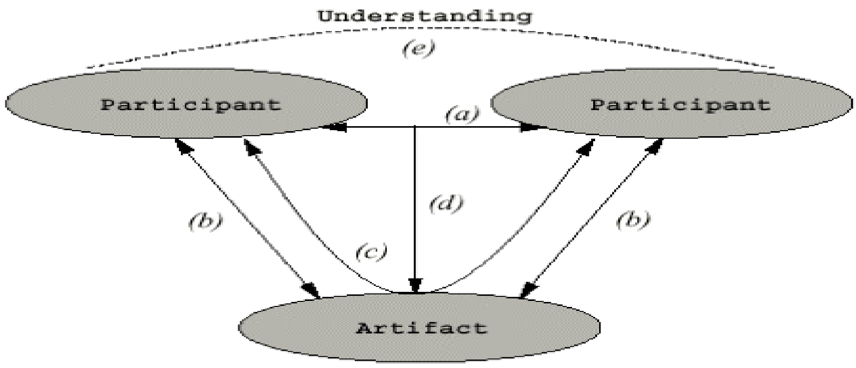


Figure 4. 9: Conceptual model of multi-user interfaces as represented by Miles et al. (1993)

As shown in figure 4.9, this model illustrates various modes or “channels” of communication between team members either directly or through a tool or “artifact”. The goal of the collaboration in the model is (e). In the model, (a) relates to direct communication between team members through speech, eye contact and physical gestures. Similarly, (d) also relates to direct communication, but it relates to the ways that team members direct each other’s attention to aspects of a shared artifact. Examples include indicative gestures like pointing with the hands or the use of a laser pointer to draw the other team members’ attention to an aspect of a shared artifact. In the model, indirect communication comes when team members change or manipulate the artifact privately (b) or do this collaboratively, together in public (c). The essential difference between channels (d) and (c) is that the first is showing aspects of a shared artifact whereas the second is the changing, editing or manipulation of the shared artifact.

Huifen et al. (2003) defined four different modes of multi-agency collaboration which can be linked to the model above. These modes are face-to-face (team members working at the same location at the same time), synchronous distributed (working in different locations but at the same time), asynchronous (working at the same location but at different times) and asynchronous distributed (working in different locations at different times).

Multi-agency partnerships in emergency management in England are made up of representatives from Category 1 and 2 responders (Sircar et al., 2013). In risk assessment activities, these representatives are co-located, meaning that they are in a face-to-face environment with a significant opportunity for direct and indirect communication. Research has found that this is the most productive way for groups to operate (Ocker, 2001). As a result, this research will focus on ways to enhance multi-agency collaboration in a co-located space by the creation of an artifact which enables and promotes direct and indirect communication.

Figure 4. 10 shows how Miles et al.'s model of multi-user interfaces (1993) has been applied to the risk assessment process by the author. This framework gives the stages of the risk assessment process, an explanation of the activities relating to each one, and the channels of interaction and communication required between the team members and artifacts in order to enhance collaboration.

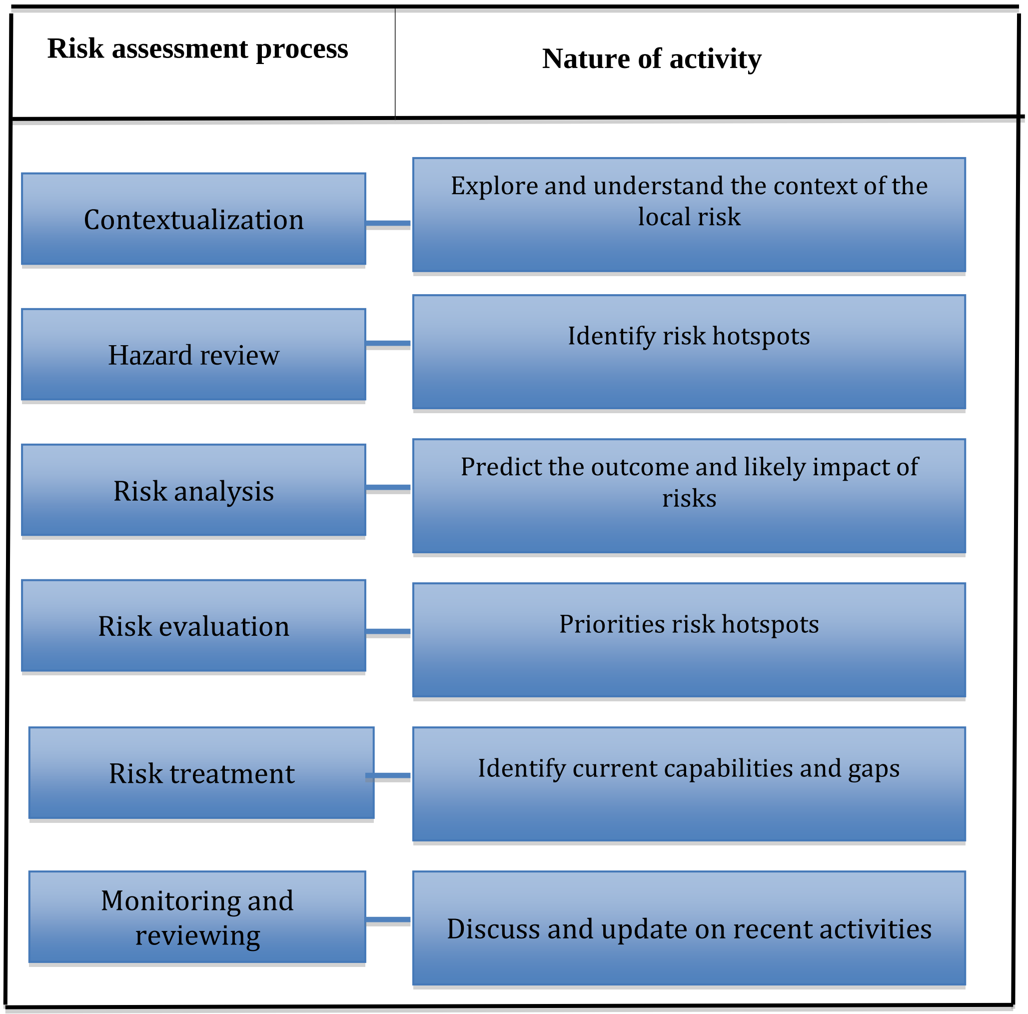


Figure 4. 10: A framework to illustrate the communication and the integration of risk assessment activities in co-located multi-agency meetings.

This model shows the channels of communication in a face-to-face co-located working environment for multi-agency teams in their risk assessment activities. In the contextualization stage, team members have to understand the context and the level of local risk by exploring social vulnerability, the local environment, the local critical infrastructure and hazard sites' information in their area. This requires direct communication as in channel (a) when team members verbally discuss local risks and in channel (d) when they collectively view and discuss the artifacts that they are using (such as maps, tables, reports, photographs etc.). It also requires indirect communication as in channel (c) when they navigate, annotate and manipulate these artifacts.

At the hazard review stage, team members identify risk hotspots based on past experience, historical data, research or other information. This involves direct communication as in channel (a) when individuals verbally discuss their experience and thoughts and in channel (d) when they, for example, view and discuss reports and studies. Moreover, indirect communication as in channel (c) is required when they edit and manipulate such reports and studies. In the next stage, risk analysis, multi-agency teams seek to predict a local risk's outcome and impact. This stage will require direct communication as in channel (a) when team members share their thoughts and speculate on a risk's likely impact and in channel (d) when they view, for example, maps of an area. Indirect communication as in channel (c) is needed if they highlight areas of a map which may be under threat from a local risk.

At the fourth stage, risk evaluation, members of multi-agency teams aim to collaboratively identify and prioritise local risk hotspots. This needs direct communication as in channel (a) in which team members give and justify their opinions and negotiate a list of priorities as well as in channel (d) if they view artifacts to support their opinions. Indirect communication as in channel (c) is needed if they annotate these artifacts to help them in prioritising.

In risk treatment, team members attempt to identify their current capabilities to deal with risks and locate gaps in their resources. This requires channel (a), direct communication, whereby team members verbally summarize their agencies' resources; channel (d), direct communication, if they collectively view maps showing the location of equipment, and (c) indirect communication if they annotate and highlight these maps.

Finally, at the monitoring and reviewing stage, multi-agency teams will require channel (a), direct communication, in order to discuss and update each other on recent activities and changes. Additionally, they will need channel (d), direct communication, if they use visual artifacts like maps or photographs to show the outcomes of activities and channel (c), indirect communication, when they update or edit their documents and records.

4.5 A Theoretical Framework for Facilitating Multi-agency Collaboration in Risk Assessment Activity

An analysis of the activity theory and critical thinking and team collaboration models has guided the researcher to identify the requirements of a collaborative environment platform for risk assessment activities. As shown in Figure 4. 11, various elements from these models have been extracted to undertake this, with each model highlighting different aspects of multi-agency activities.

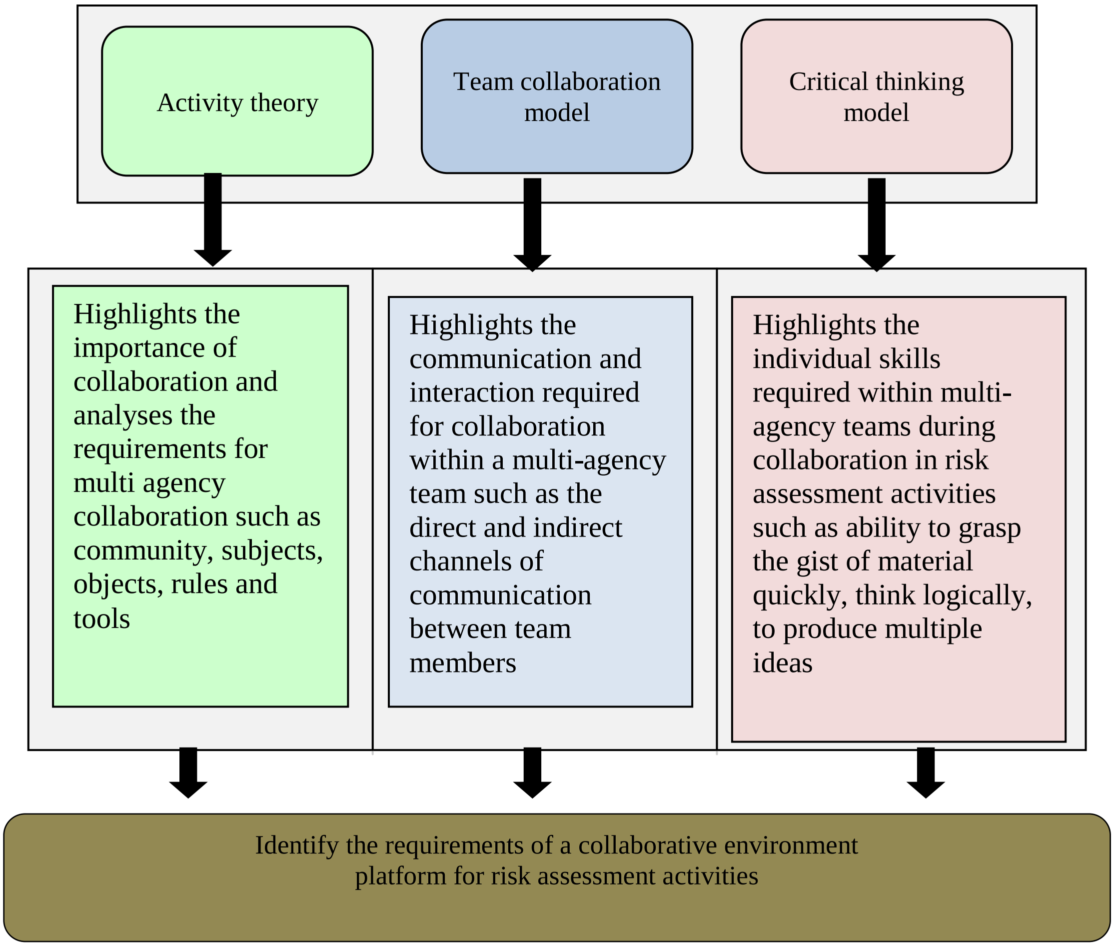


Figure 4. 11: A theoretical framework for facilitating multi-agency collaboration in risk assessment activity

This research has applied the activity theory to a specific professional body working towards city resilience, namely the Greater Manchester LRF. When applied to this example, the activity theory highlights the importance of collaboration and analyses the requirements for this collaboration. The elements of the activity theory that guide this research are: community, subjects, objects, rules and tools. The community in this context is Category 1 and 2 responders in Greater Manchester. From this community, the researcher defined the subjects who need to be targeted for the collection of primary data. These were the commanders of each agency within Greater Manchester LRF. Another key element are their objectives which, in this case, is the completion of risk assessment activities and the understanding of local risks. Rules in this context cover the comprehensive approach to disaster management which, in this case, are the Integrated Emergency Management guidelines and, specifically, risk assessment processes. Tools are the final aspect of the activity theory guiding this research investigating the technological platforms currently available, and guiding the development of tools that are successful in supporting multi-agency collaboration. The activity theory's concept of contradiction has also guided this research, because professionals engaged in collaborative risk assessment face numerous problems in their work, such as a lack of good communication within their team (a primary contradiction) or difficulties in using their technical tools (a secondary contradiction).

The team collaboration model has highlighted the communication and interaction required for collaboration within a multi-agency team. The key elements within this model are interaction processes, teams, individuals and tasks. Interaction processes give an understanding of the direct and indirect channels of communication between team members and their tools and artifacts (such as interactive maps). Teams and individuals have also been utilised to guide this research because LRFs are teams made up of individual members. Similarly, an understanding of the tasks faced by multi–agency team members is required in order to enhance the interaction and communication needed for effective collaboration.

The critical thinking model highlights the individual skills required within multi-agency teams during collaboration in risk assessment activities. This model guides the design of a collaborative platform, highlighting the need for the design to reduce the negative effects of critical thinking such as tiredness, anxiety and social awkwardness. Moreover, this model outlines the critical thinking skills that such a platform should promote in order to support multi-agency team members' collaboration. These skills are interpretation skills (such as the ability to grasp the gist of material quickly) reasoning skills (such as the ability to think logically), assessment skills (such as evaluating old information in light of new information) and meta-cognitive skills (such as the ability to consider a number of alternative explanations for an event). In addition, the critical thinking model provides a means of evaluating the success of the prototype platform. The next section discusses the specific influence of theories on prototype design.

4.5.1 Influence of Theories & Model on Prototype Design

The application of the activity theory in the design of the prototype: The activity theory provides an analysis and an understanding of humans' interaction through their use of tools and artefacts, as identified in previous sections in this chapter. This is achieved through providing the users with artefacts (Engeström, 2001) which, in the case of this study, is an interactive map that can present the risk models via various visual layers on top of the map to the users. Google Earth is used by this map as a plugin in a web browser that can run on the user's computer.

The application of the Critical Thinking Model: the ability to retrieve the gist of any material is achievable in that the users can retrieve the information in each layer of the interactive map and scrutinise a piece of information they particularly need (Fischer et al., 2009). Each layer of the interactive map provides a type of information so the task of the user is broken into sub-tasks and so are their goals. In the first layer the users can recognise the levels of flood in a particular area where the high-risk areas are coloured with dark blue and the low-risk areas are coloured with light blue. Demographic information is provided on another layer, and so on. In this case, users are able to make decisions and judgements based on balancing different factors. Additionally, the users have come to the task with previous assumptions. The information provided by the layers of the interactive map can encourage the users to think logically and compare between their schemata about the subject and what is discovered within the layers; either they confirm their already existing schema or they challenge them.

Team Collaborative Model: the workgroup approach has been used in this study. The participants will be involved in a discussion and they will be monitored while discussing and exchanging points of view and comments. During the task, they exchange opinions and comments on the information provided by the map. They model a plan based on what they have found in the interactive map layers. They set a deployment stage to which the plan is released. A round of communication takes place between the participants and designers and they give feedback on the project.

Overall, the activity theory is used as a way of guiding the development and use of tools and systems to achieve a specific objective. In the case of this research, the activity theory provides a way of analysing the activities undertaken between multi-agency LRFs as they work towards their common objective, which is to meet and complete risk assessment activities in order to achieve resiliency and preparedness in the local community. The collaboration model helps to understand how the multi-agency teams can communicate, interact and collaborate, while the critical thinking model provides a means of understanding and improving the way that these teams should understand the information to which they have access. Overall, the analysis of the above models points to the need to identify the specific requirements for a collaborative platform for risk assessment activities.

4.6 Summary

This chapter has analysed the activity theory, the critical thinking model and the team collaboration model to identify the theoretical aspects that should be considered in developing a collaborative environment for risk assessment activities. Firstly, the activity theory guided the collection of secondary data in the literature review and the research questions. Moreover, it gave a way of understanding the community, subjects, objects, rules and tools involved in collaborative risk assessment. Secondly, the critical thinking model has identified the critical thinking skills needed in order to support multi-agency team members' collaboration and the negative effects that need to be minimised. Finally, the team collaboration model has been used to identify the communication and interaction channels necessary for multi-agency collaboration. In the next chapter, detailed information is presented on the research design, the research philosophy, the research approach and the research techniques used in this thesis to achieve the aim of the thesis.

Chapter 5 – Research Design

5.1 Introduction

In this part of the thesis, detailed information on the methodology adopted for this research is discussed and justified. This chapter is divided into different sections with each section discussing and justifying the research philosophy, approaches, strategies and choices of techniques used for this research. Other sections in this chapter also examine the techniques and procedures utilised for data collection and analysis which are an integral part of the research outcome. This chapter uses the 'research onion' put forward by Saunders et al. (2009) as a working guide to explain the research process. As a lead in to this, this chapter starts with discussing the context for research methodology as undertaken by the researcher for this research.

5.1.1 Definition and Discussion on Research Methodology

Antony et al. (2002) explained research methodology as the steps and processes needed to guide a researcher in order to achieve the objective of the research. But additionally, Hussey et al. (1997) defined research as "different things to different people" so there is no consensual definition of what research is. Nevertheless, Sekaran (2009) argued that research is simply the process of finding solutions to a problem after a thorough study and analysis of the situational factors. On the other hand, Collis and Hussey (2009) identified research methodology as referring to the overall approach to the research process, from the theoretical underpinning to the collection and analysis of the data. According to Hussey and Hussey (1997), the purpose of research can be explained as follows: "to explain a new phenomenon, to investigate some existing situation or problem, to provide solutions to a problem, to explore and analyse more general issues, to construct or create a new procedure or system, to review and synthesise existing knowledge, to generate new knowledge, or any combination of the above".

There are several methodological frameworks that have been presented and explained by different writers. However, for the sake of clarity, this research adopts the Saunders et al.'s (2009) 'research onion' methodological framework.

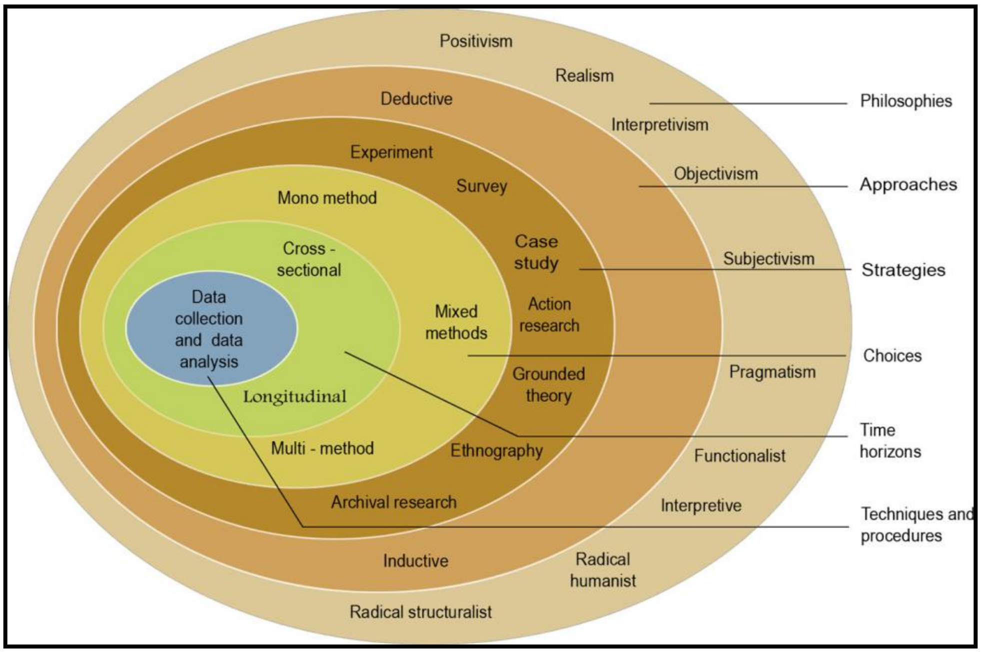


Figure 5. 1: Research Onion (Source: Saunders et al., 2009)

As shown in Figure 5. 1, Saunders et al. (2009) explained the research methodological process as one with different, but related, layers that interact in order to ensure the successful completion of the research process. The 6-layer process is used to explain and justify the decision taken by the researcher to use the methods discussed in this chapter for conducting the research study. According to Saunders et al. (2009), the first layer which is the philosophical stance is important as the starting point for any researcher. Travers (2001) explained that it is vital for a researcher to understand the underlying philosophy of research in order to adopt the most appropriate research approaches and methods.

5.2 Research Philosophy

An understanding of philosophical issues is very significant. Mostly, it can help to clarify the research design, detect which research design will work and which will not, and identify (and even create) designs that may be outside the researcher's past experience (Easterby-Smith et al., 2008). The term 'research philosophy' relates to "the development of knowledge and the nature of that knowledge" (Saunders et al., 2007). The research philosophy that a researcher adopts contains important assumptions about the way in which they view the world (Saunders et al., 2007). These assumptions support the research approach and the methods chosen as part of that approach (Saunders et al., 2007). Whereas, from time to time, the researcher’s practical experience in the subject area can also play a role in deciding the philosophical assumptions, inferring that the foremost deciding factor is the researcher's particular view of the relationship between knowledge and the process by which knowledge is developed (Saunders et al., 2007).

Saunders et al. (2009), in the ‘research onion’, identified six different philosophical stances which can be adopted by any researcher to explain and justify their views, the research inquiry process and the validity of results. Positivism generates a hypothesis or research questions that can be tested and allows for explanations that are measures against accepted knowledge (Creswell, 2012). This philosophy is similar in concept to objectivism which recognises that social phenomena and their meanings exist separately to social actors or to any social influence factors (Easterby-Smith et al. 2008). Another philosophy in the ‘onion’ with a similar assumption to scientific, objective and non-social influence is realism philosophy. This philosophy shares the positivism assumption that processes and beliefs are scientifically generated. The researcher and other social actors are independent of any findings generated by this philosophy and thus the results are not biased (May, 2011).

Therefore, interpretivism, pragmatism and constructivism are similar in their underlying assumptions which emphasise the impact and the meaningful influence of people’s participation in the existence and construction of social phenomena (Creswell, 2012). Therefore, it can be argued that all philosophical traditions or underlying assumptions are from two main stems i.e., 'positivism' and ‘interpretivism’ (Easterby-Smith et al. 2008). "The key idea of positivism is that the social world exists externally and that its properties should be measured through objective methods, rather than being inferred subjectively through sensation, reflection or intuition" (Easterby-Smith et al., 2008). In contrast, the interpretivism paradigm assumes that "reality is not objective or external but is socially constructed and given meaning by people" (Saunders et al. 2012). In accordance with the discussion above, Table 5. 1 shows how Saunders et al. (2012) described the differences between the positivist and interpretive research approaches.

Table 5. 1: The differences between the positivist and interpretive research approaches (Saunders et al., 2012)

Question	Positivism	Interpretivism
What is the nature of reality? (**Ontology**)	Something that is external to the social world.	Something that exists in the socially negotiated meanings that people give to it.
What is considered as acceptable knowledge? (**Epistemology**)	Knowledge based on observable phenomena. Suitable for generalisation	Knowledge about subjective meanings. Details of specific cases
What is the role of values? (**Axiology**)	Research should be value-free.	Research is shaped by values.

Saunders et al. (2012) outlined the main differences between positivism and interpretivism: Firstly, positivism uses large samples, has an artificial location, and is often concerned with hypothesis testing, producing precise and objective quantitative data, producing results with high reliability but low validity, and allowing results to be generalised from the sample to the population only. Secondly, interpretivism uses small samples, has a natural location, and is concerned with generating theories, producing 'rich' subjective, qualitative data, and producing findings with low reliability but high validity based on social phenomena.

As can be seen from all these clarifications, this research intends to explore and investigate the influence of a collaborative risk assessment environment that can enhance multi-agency collaboration in risk assessment in order to enable participants to visualise and analyse various risks through an interactive map. This research is an example of social phenomena in that it deals with attitudes, experience, realities and beliefs in a specific environment, and also the way in which these ideas are changed between persons. This research adopts the interpretivist philosophical stance due to the above explanations and the justification presented throughout this chapter. As such, all corresponding characteristics of interpretivism was also adopted by the researcher for conducting this research. For instance, qualitative data, the use of small samples, and an in-depth understanding of the phenomena were all adopted with the rationale for their selection justified subsequently in this chapter.

In the context of philosophical assumptions, there are three major ways of thinking about research philosophy as summarised by Engle (2008). Firstly, Ontology is the "the science of being" of substances. The object of ontology is to determine 'What is'. Secondly, Epistemology is the science of knowledge that is the theory of how we know that which we know. Epistemology is by nature self-referential or recursive. Finally, Axiology is the science of moral choice, of fundamental values.

Although ontology, epistemology and axiology are different from each other, each one influences the technique by which a researcher thinks about the research process (Collis and Hussey, 2003; Creswell, 2007; Easterby-Smith et al., 2008; Saunders et al., 2007). The following sections, sections 5.2.1, 5.2.2 and 5.2.3, discuss ontology, epistemology and axiology in detail.

5.2.1 Ontology

'Ontology' is a starting point for philosophical assumptions and is concerned with the assumptions that researchers make about the nature of reality (Creswell, 2007; Easterby-Smith et al., 2008). In an ontological assumption, there are two different worlds: the first world is objective and external to the researcher, whereas the second world is subjective and is only understood by examining the perceptions of human actors (Collis and Hussey, 2003). In the objective stance, the external world has a predetermined nature and structure which is known under different terms by different authors, such as 'realism' by Johnson and Duberly (2000) and 'objectivism' by Saunders et al. (2007). On the other hand, in the subjective stance, the external world does not have a pre-determined nature or structure. In other words, it is an unknowable reality perceived in different ways by individuals; this is called 'subjectivism' by Saunders et al. (2007) and 'idealism' by Gummesson (1991).

Qualitative research is a field of investigation concerned mainly with the subjective interpretations of people (Denzin and Lincoln, 2005). As indicated by Deniz and Lincoln (2005), the qualitative researcher’s purpose is to gather an in-depth understanding of human behaviour and the reasons that govern such behaviour. Therefore, in this context, this research has taken more of an ‘idealist' stance because the meanings given to disaster management and to a collaborative risk assessment environment for multi-agencies may differ from one to another depending on their understandings.

5.2.2 Epistemology

The epistemological assumptions of a researcher are useful in guiding him/her to take up methods that are consistent with his or her initially accepted epistemology (Easterby-

Smith et al., 2008). Hence, having a clearer idea about the epistemological undertakings of the research study is crucial. The main two philosophical traditions in epistemology have been classified into Positivism which believes that researchers should use objective measures, and Interpretivism which believes that they should measure using subjective measures.

In positivist research, the epistemological assumption adopted is the use of objective measures in order to search for general laws and cause-effect relationships by rational means (Easterby-Smith et al., 2008). In contrast, in interpretivist research, the epistemological assumption adopted is the use of subjective measures in order to search for explanations of human action by understanding the way in which the world is understood by individuals (Easterby-Smith et al., 2008). Under this extreme epistemological assumption, it is assumed that properties of reality can be measured through interpretivism (subjective measures) and determined by examining the perceptions of people (Collis and Hussey, 2003; Easterby-Smith et al., 2008). The epistemological assumption in interpretivist research means that, in a qualitative study, researchers try to become as close as possible to the participants (Creswell, 2007). Therefore, in this research study the epistemological assumption of interpretivist research has been adopted using subjective measures. In order to collect the characteristics of an interactive map for use in multi-agency risk assessment activities, it was necessary to conduct face-to-face, semi-structured interviews with stakeholders. As such, this study adopted the interpretivist stance, with the researcher getting directly involved with the participants.

5.2.3 Axiology

Axiology is the last step within research philosophy and studies judgments about value (Saunders et al., 2007). Moreover, Creswell (2007) and Saunders et al. (2007) identified 'axiology' as the assumptions about the nature of values that the researcher places on the study. Collis and Hussey (2003) explained that, within axiology, a value-free study means that the choice of what to study and how to study it can be determined by objective criteria, i.e. in value-free research. Positivists believe that the objects they are studying are unchanged by their research actions. On the other hand, value-laden follows an extremely different opinion as choices in the research are determined by human beliefs and knowledge (Easterby-Smith et al., 2008). As this study sought to investigate human experiences in the field of collaboration in risk assessment in disaster management, it adopted a value-laden stance in relation to axiology. By being asked about their preferences and then introduced to a prototype interactive map, participants were altered by the actions taken by the researcher. This approach was necessary in order to achieve the aims of the research.

Figure 5.2 depicts the placing of this research within ontological, epistemological and axiological stances. The Figure includes three lines representing the epistemological, ontological and axiological spectrums. As can be understood from the explanations given, interpretivism is the research philosophy that was most appropriate for this study because the study is concerned with the actions of people and the meanings behind these actions. As a result, the research is positioned at the intepretivist end of the epistemological spectrum in the Figure. Moreover, because the research has explored an interactive map that can enhance multi-agency collaboration in risk assessment in disaster management, the 'idealist' stance was more appropriate in terms of ontological assumptions. Therefore, on the Figure the research is located at the idealist end of the ontological spectrum. Finally, the research is positioned at the value-laden end of the axiological spectrum because it sought to influence the behaviour of its participants by developing an interactive map for them to use.

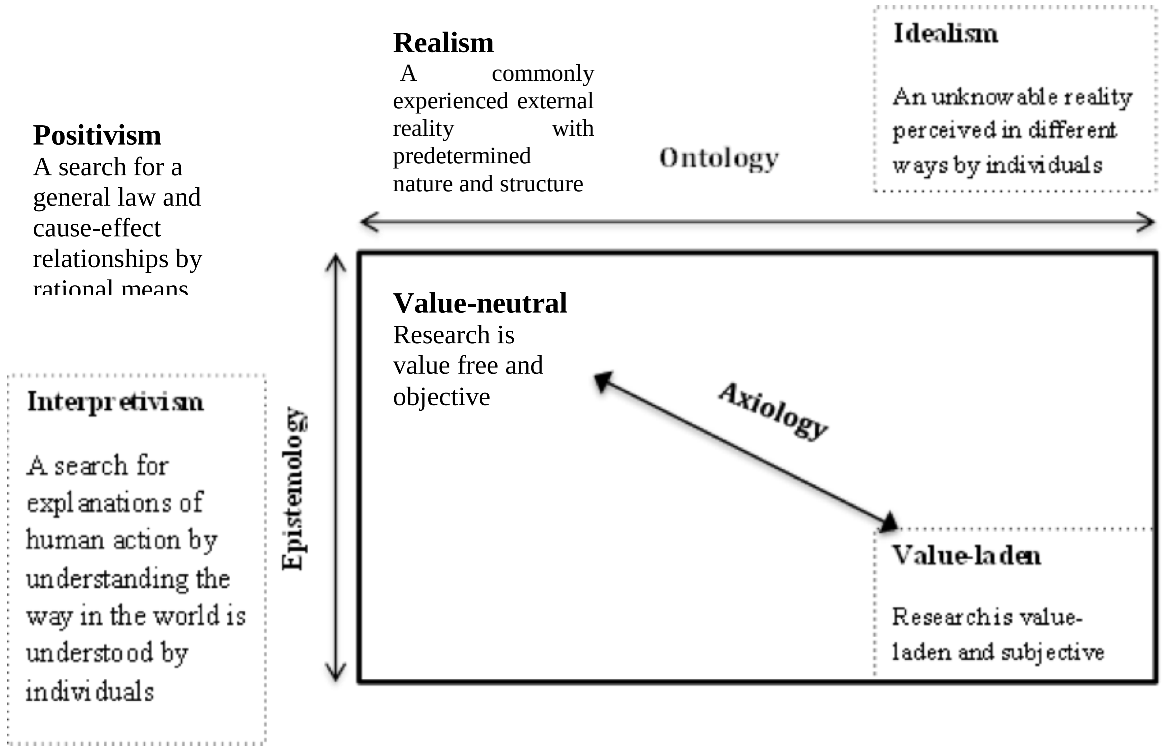


Figure 5. 2: Research's positioning within philosophy i.e., within the ontology, epistemology and axiology stances

5.3 Research process

The research design process is explained in the figure 5.2. The first chapter is the identification of the research problem, the setting of a specific research question and then the provision of detailed clear aims and objectives for the research. The second chapter focuses on evaluating existing organisational structure for disaster management across the world in order to make comparison and identify gaps and problems. This chapter provided context for the research especially for the focus in chapter three which is dedicated to technology approaches used for supporting disaster management. Chapter four provide a theoretical foundation for this research, with investigations into the Activity Theory, Critical Thinking, models of team collaboration and into a theoretical framework for this study. The next chapter is the research's design. This involves describing its philosophy and outlining the research approach and research techniques for the collection of data. Chapter 6 presents the outcome of the interviews conducted to identify the user requirements for the interactive map. Chapter 7 describes the possibilities for the design of the system and the conceptual framework of the design and the implementation of the system. Chapter 8 describes the evaluation of the interactive map prototype in order to test its ability to support collaboration and to enhancing multi-agency teams' risk assessment process. After this prototype was defined, it was necessary to provide a methodology for the evaluation of the system, which is described in Chapter 8. Chapter 9 presents the evaluation results collected during the evaluation experiment of the interactive map prototype, while Chapter 10 discusses the findings and their implications in reference to the literature. It also presents the limitations of this research. Finally, Chapter 11 presents an overall conclusion to this research and the extent to which it has achieved its aims and objectives and gives recommendations for future research in this field.

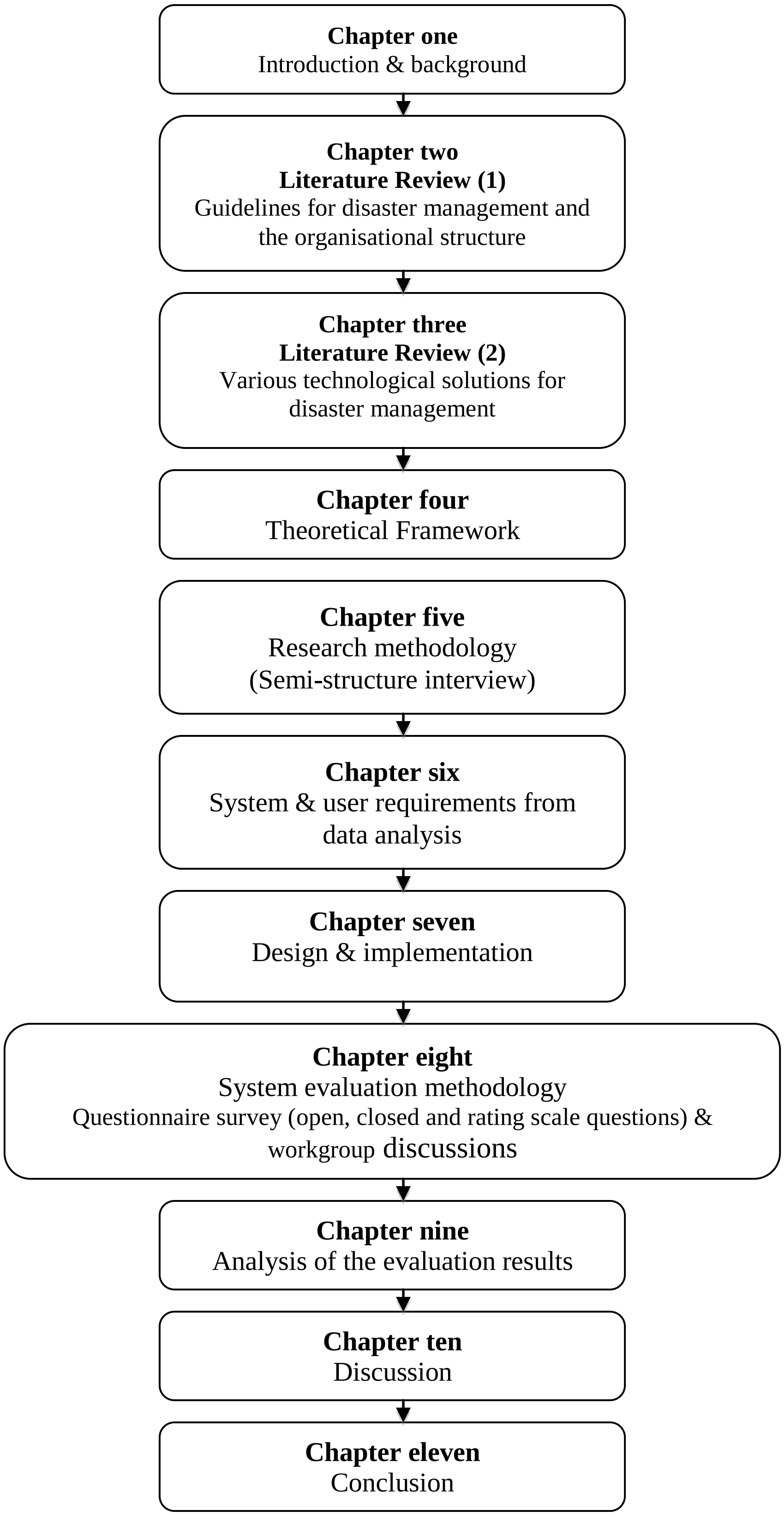


Figure 5.2: The research process

5.3.1 Theoretical Justification for Interpretivism

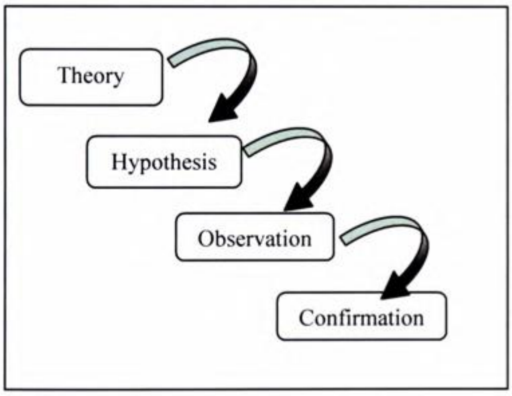
The theoretical underpinning for this research also justifies the choice of the interpretivism philosophical stance. As explained in the previous chapter on theories, the activity theory (which is the theoretical framework for analysing and understanding human interactions) aligns with the characteristics and processes for the interpretivism explanation of the phenomena being researched. Through a philosophical stance, the application of the activity theory enables a thorough discovery of the approaches that can encourage collaborative working for risk assessment between agencies involved in emergency and disaster management. As explained by Hashim and Jones (2007), the application of the activity theory facilitates rapid processes and constant change within organisations and this theory is utilised through the interpretivism philosophical stance in this research.

The activity theory is able to facilitate the analysis of research results in a manner that helps to identify structures and in a manner in which collaborative risk assessment can be more effectively undertaken by multiple agencies. The influence of the activity theory does not only align with the inherent characteristics of the interpretivism philosophy, it also enables the exploration of knowledge of multi-agency collaboration as intended by the researcher. It ensures that the researcher focuses on collaborative work between all agencies, thereby emphasising the role of the team collaboration model as well as the critical thinking model in achieving valid research outcomes.

The domain for the critical thinking model relates to six areas which are knowledge and recollection of information, identifying and understanding problems, applying existing concepts to new demands, analysis of information, forming patterns and evaluating ideas and making judgments about the value of ideas. These six cognitive areas also influence the selection of the research participants on the basis of their ability to engage, to provide information, and to identify and understand problems associated with collaborative working for risk assessment. By utilising these areas the researcher is able to form patterns from the responses provided as well as being able to make rational decisions on their classification based on their ontology and relevance to the epistemology in this subject area. In order to understand this process better, sections 5.4, 5.5 and 5.6 explain and justify the research process, approach, strategy, choice, horizon, techniques and procedures.

5.4 Research Approach, Strategy and Choice

This section discusses the second, third and fourth layers in Saunders et al.'s 'research onion'. According to Saunders et al. (2009), there are two main approaches for reasoning and knowledge in a research. These two approaches are deductive and inductive logic or reasoning. Invariably, deductive reasoning works from the more general to the more specific (Saunders et al., 2009). Sometimes this is informally called a "top-down" approach, as a research might begin with thinking up a theory about a topic of interest and then narrowing the thought down into more specific hypotheses that can be tested (Trochim, 2006). It can be even further narrowed down when observations are collected to test the hypotheses, as illustrated in Figure 5.3 below. The inductive approach, on the other hand, is the opposite, as shown in the same Figure, 5.3.



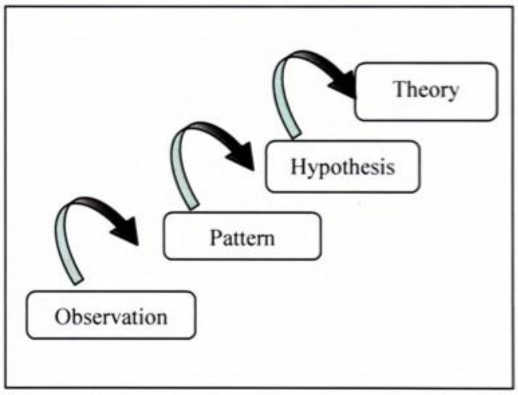


Figure 5. 3: Deductive and Inductive reasoning approaches (Trochim, 2006).

Although Figure 5.3 is lucid enough, Trochim (2006) and Saunders et al. (2009) argued that the hypothesis in each case can be research questions. Inferring that for deductive reasoning, the aim is solely to test the validity of the research hypothesis or question, without any intention to build knowledge or contribute to advancing a research area. This approach is consistent with the positivism philosophy and with scientific experiments conducted in laboratories to test a theory or confirm a hypothesis (Saunders et al., 2009). However, the inductive process may start from a set of observations, research questions and social phenomena subjected to critical inquiry or an investigation process. According to Trochim (2006), patterns of outcomes are then aligned to explain the research questions from which a new theory, knowledge or framework can be developed based on the research outcome(s). According to Yin (2009), these two approaches can be exploratory in nature. But as explained by Saunders et al. (2009), inductive logic is known to be descriptive, analytical and explanatory in nature when subjected to a theory or knowledge, developing a process as illustrated in Figure 5.3.

Since this research has adopted the interpretivism philosophy, inductive is the approach specific to interpretivism. As shown in Figure 5.3, the intention of the researcher is to investigate the nature of an interactive map that can enhance multi-agency team collaboration in the risk assessment process in disaster management. This investigation process has been initiated based on a set of assumptions and research objectives that focus on developing an interactive map. The influence of the activity theory, the collaborative model and the critical thinking theory have all provided patterns that suggest an interactive map can be designed to enhance multi-agency team collaboration. However, there is need to further investigate the essential features and the extent to which risk assessment in disaster management can be enhanced, hence the need for primary data collection and an inquiry process beyond secondary data and existing theories.

Using primary data for this research stresses the importance of the third layer in the 'research onion' which is strategy. As seen in the strategy layer, there are the options of action research, experiments, archival research, ethnography, grounded theory, surveys etc. that can be used for conducting research (Saunders et al., 2009). However, selecting the most suitable strategy or strategies is also vital to the success of a research project (Robson, 2002). For example, Saunders et al. argued that more than one strategy can be selected to conduct a research; a choice can be made based on the nature of the inquiry, objectives and problems being investigated. This possibility leads to the fourth layer, choices. Choices, as mentioned in the 'research onion', refer to the research style adopted for collecting and analysing the data. The 'research onion' has identified three types of method, namely, the mono method, mixed methods and multi-methods.

The mono method can be defined as either using quantitative or qualitative data for a research project (Saunders et al., 2009). Mixed methods refers to the use of both quantitative and qualitative data which are analysed using a data analysis method peculiar to each type of data (Saunders et al., 2012). Multi-methods is when the researcher uses both quantitative and qualitative data, but the researcher's philosophical stance is rooted in only one philosophy and all data are analysed using one analysis tool (Saunders et al., 2012).

This research focuses on developing a platform to support collaboration in risk assessment activities among multi-agency teams in disaster management. Therefore, due to the need to develop a platform, the inductive approach is adopted. Also, to achieve the research aim, the context and nature of the problem must be identified, which is why the inductive approach is relevant and important to this research investigation. Therefore, this research investigation process began by identifying the organizational problems faced by the Manchester LRF in its risk assessment activities. The semi-structured interviews were conducted with the senior managers within Category 1 responders in The Greater Manchester Local Resilience Forum (GMLRF) to capture the requirements for a multi-agency collaboration platform. The outcomes from the interviews' analysis was used to capture the characteristics and to develop the prototype of an interactive map that can enhance multi-agency team collaboration in the risk assessment process in disaster management.

The validation of the interactive map prototype was conducted by involving senior practitioners from stakeholders in the GMLRF development group. The experiment was held in the THINKpod in ThinkLab, at the University of Salford. A total of 23 senior practitioners took part in the evaluation experiment. After a demonstration of a scenario using the interactive map, the participants evaluated the prototype via a work group discussion and then completed questionnaires that featured a range of open, closed and rating scale questions. The data collected from the work group discussions and the open and closed ended questions in the questionnaire were analysed qualitatively. However, some of the data that had been collected from the rating scale questions were manipulated statistically for descriptive analysis. The outcomes from the analysis process of the data were used to measure the 'perceived effectiveness' of the potential of the interactive map in supporting risk assessment processes and in strengthening the collaboration between multi-agencies.

Due to this combined technique, the research choice is mixed methods, in order to ensure that both qualitative and quantitative data were collected. Most of the research outcomes were based on qualitative data analysis. However, the data that was collected from the rating scale questions was used for descriptive analysis and also for system evaluation. Adopting the mixed-methods approach for this research is justified within the interpretivism philosophy and the inductive approach for building knowledge in this research area. This is because both types of data are important to validate the platform that this research aims to develop for enhancing the collaborative process for risk assessment.

Using the inductive approach for this research also helped to identify and investigate the themes that emerged when end users were involved in the evaluation of the interactive map prototype in a co-located environment at the Think Lab at the University of Salford. This real life scenario and engagement contributed to increasing the validity and reliability of the results. An observation and demonstration of the platform was followed by user feedback in the form of a discussion and a questionnaire utilising open, closed and ratings' scale questions. Using this mixed methods approach helped to collect different, but complementary, types of data that made triangulation possible, thereby increasing the validity and reliability of the results.

5.5 Research Horizons and Procedures

The horizon, techniques and procedures are the fifth and sixth layers of the 'research onion' respectively. This section discusses the time horizon for this research and the techniques and procedures utilised for analysing the data collected. The horizon refers to the time in which the research was conducted. According to Saunders et al. (2009), there are two time horizon choices, one being cross-sectional which refers to a study conducted over a short period of time. The second option is the longitudinal time horizon which refers to a research conducted for a protracted period of time i.e. studying concentrated samples for a long period of time (Saunders et al., 2012). The cross-sectional time horizon was used to conduct this research, as several research activities were carried out during a fixed period of time. During the fixed period utilised for conducting this research, the research techniques i.e. the questionnaire administration and the semi-structured interview sessions (briefly mentioned in the last section) were simultaneously conducted.

5.6 Research Techniques

This section discusses the research techniques used in this study. Firstly, data collection techniques were decided through the influence of interpretivism, theoretical constructs and the ability to ensure that the research objectives were achieved. Secondly, data analysis (which is the procedure by which data were coded, interpreted and analysed) completed this part of the procedure. In section 5.6.1 data collection techniques are explained in general and then later with regard to this particular research (which included semi-structured interviews to capture the views and reactions of stakeholders. The questionnaires (including open, closed and rating scale questions) were administered and a work group and discussions were held to evaluate the effectiveness of the interactive map prototype. Section 5.6.2 explains the data analysis procedures and the different types of techniques used for analysing all the data collected during the cross-sectional time horizon.

5.6.1 Research Techniques for Data Collection

The many different research techniques for data collection are explained in this section. Techniques include interviews, observations, questionnaire surveys, audio-visual materials and document reviews. Although Saunders et al. (2009) classified these techniques as strategies for data collection in layer 3 in the 'research onion', Yin (2009) recommended six major sources of data collection techniques or strategies which can be used for data collection. Table 5. 2 outlines these six major data sources and explains their strengths and weaknesses.

Table 5. 2: Six major sources of data collection techniques (Source: Yin, 2009)

Source of evidence	Strengths	Weaknesses
Documentation	- Stable: Can be reviewed repeatedly - Unobtrusive: not created as a result of the case study - Exact: contains exact names, references and details	- Retrievability can be low - Biased selectivity, if collection is incomplete - Reporting bias: reflects bias of the author - Access: may be deliberately blocked
Archival Records	- Same as above - Precise and quantitative	- Same as above - Accessibility may be limited for privacy reasons
Interviews	- Targeted: focuses directly on case studies - Insightful: provides perceived causal inferences	- Bias due to poorly constructed questions - Response bias - Inaccuracies: interviewees say what they think the interviewer wants to hear
Direct observation	- Reality: covers events in real time - Contextual: covers context of event	- Time consuming - Selectivity: poor, unless broad coverage - Reflexivity: events may be processed differently
Participation / direct	- Same as for direct observation	- Same as for direct observation

observation	- Insightful into interpersonal behaviour and motives	- Bias due to investigator's manipulation of events
Physical Artifacts	- Insightful into cultural features - Insightful into technical operations	- Selectivity - Availability

The importance of utilizing interviews, as explained by Yin (2009), can be attributed to the fact that they give access to people's views, to deep insights into a situation, into the sense and identification of a situation, and deal with human concerns. Furthermore, Jonse (1985) and Punch (2005) stressed the importance of interviews in understanding a situation: "in order to understand other persons' construction of reality, we would do well to ask them …. and to ask them in such a way that they can tell us in their terms (rather than those imposed rigidly and prior by ourselves) and in a depth which addresses the rich context that is the substance of their meaning". On the other hand, questionnaire survey techniques are the best way of gathering data from a large sample of participants (Saunders et al., 2007).

In this study, there was not one overarching period of data collection. The study involved firstly capturing the characteristics of a desired system from the stakeholders. In this phase, the researcher collected the data from different agencies (from senior managers in the field of risk assessment) with a view to capturing the characteristics which constitute the system requirements for a collaborative risk assessment environment in the form of an interactive map that can enhance multi-agency collaboration in risk assessment. This was a distinct part of data collection. Then, after the system had been developed, a second distinct phase of data collection followed, in which the system was evaluated.

Therefore, in the first phase, the researcher employed semi-structured, face-to-face interviews as the main method of data collection to capture the characteristics of the desired system. Then, in the second phase, a questionnaire survey (made up of open, closed and rating scale questions), a workgroup, and discussions were used to evaluate the interactive map prototype. This combination of different techniques was used in this study to minimize the weaknesses of each individual technique and to satisfy the requirements for research validity and reliability. This is in line with the recommendation of Yin (2009) who suggested that using more than one method to collect data is important. Thus, in this study the triangulation technique was adopted by its use of many sources of evidence. According to Ghauri et al. (1995), triangulation uses a combination of methods in order to get an accurate result/accurate results concerning the same phenomena under study. This method improves the accuracy of the outcome of the study by using different methods to collect data for the research (Ghauri et al., 1995). The next section provides more details on the different types of data collection techniques used in this research.

5.6.1.1 Interviews as a Research Technique for Data Collection

As a means of collecting data, an interview is one of the most important research techniques used in field of research approaches. As indicated by Yin (2009), an interview is a crucial method of data collection. Furthermore, Remenyi et al. (1998) stated that the interview is a famous qualitative method for collecting data. Collis and Hussey (2009) explained interviews as a "method of collecting data in which selected participants are asked questions in order to find out what they do, think or feel." Interviews are most appropriate for research when a researcher wants to learn about an individual's beliefs, values, experience and knowledge in depth (Easterby-Smith et al., 2008). There are three types of interview generally used in the research community: structured interviews, semi-structured interviews and open-ended (unstructured) interviews (Easterby-Smith et al., 2008; Punch, 2005).

According to Easterby-Smith et al (2008), a structured interview is a set of questions prepared by the researcher in the same order for all the interviewed respondents. In open-ended (unstructured) interviews, the interviewees are allowed to talk freely without any interference from the researcher (Saunders et al., 2009). Furthermore, Robson (2002) described semi-structured interviews as a mix of structured and unstructured interviews where the questions are pre-set but the order in which they are raised and the period of time utilised can be changed within each topic during the interview. In addition, an advantage of semi-structured or open-ended interviews is that richer data is obtained, as the interviewees provide much more detailed information and insight in their responses (Creswell, 2012).

Moreover, as indicated by Jankowicz (2005), the semi-structured interview gives the flexibility needed for a particular kind of study, as it gives the researcher flexibility in asking the questions in the interview; additional questions can be added if the researcher feels this assists with the research. Furthermore, Saunders et al. (2009) stated that semi-structured interviews are used in qualitative research not only to show and understand the ‘what’ and ‘how’, but also to place more emphasis on explaining the ‘why’ of a given situation, especially if the research places an emphasis on words rather than numbers: on connections, on people’s behaviour, on cultural change, and on experiences and attitudes. As explained by Yates (2007), the interview is an appropriate way of exploring an interviewee’s personal views.

In short, semi-structured interviews allow for the capturing of participants’ opinions in depth and with flexibility, but with some level of organization. Such organization was required in this study in order to link the data that were captured closely to the risk assessment process. To ensure that the data corresponded to the risk assessment process, the steps of the process were used to structure the questions that were asked. For instance, some questions related to contextualisation, hazard review, risk analysis, risk evaluation and risk treatment. The aim of the interviews was to collect as much in-depth data as possible, but also to ensure that the data was closely linked to the risk assessment process. As a result, the use of semi-structured interviews was an appropriate research technique for capturing the characteristics of an interactive map that stakeholders (in this case, senior managers and departmental manager in different agencies in the field of risk assessment in the Greater Manchester Local Resilience Forum in England) found desirable.

Before arranging interviews with the strategic managers or tactical managers of agencies involved in disaster management, a pilot study was undertaken. Saunders et al. (2007) explained a pilot study as “small-scale study to test a questionnaire, interview checklist or observation schedule, to minimise the likelihood of respondents having problems in answering the questions and of data-recording problems as well as to allow some assessment of the questions’ validity and the reliability of the data that will be collected”. In addition, there are many reasons for conducting a pilot study in this phase; to validate the interview questions, to increase the value of questions, to explore the success of research method (Yusof and Aspinwall, 1999). Yin (2009) indicated that a pilot case study helps investigators to refine their data collection plans with respect to both the content of the data and the procedures to be followed.

The researcher conducted a pilot case study in order to examine whether the questions were clear to the interviewees, whether they covered the research problem and whether they avoided repetition. Moreover, this pilot study helped the researcher to estimate the duration of the interviews that would follow. The pilot study was conducted in January

2014 with four participants. Taking on board the comments made during this pilot study, the researcher modified the interview questions.

An interview guideline was prepared prior to interviewing the respondents using semi-unstructured interviews. Yin (2009) recommended preparing a brief introduction on the aims of the research and the purpose of interview which should be presented to each interviewee, otherwise the data collection could be unsuccessful. This was achieved by giving a brief to the participants on the aim of study, the aim of interview, and the benefits of this study to the organization. It was felt that this would motivate the participants and encourage them to think clearly about the topic of their risk assessment activities and their needs in this area.

5.6.1.2 Sampling

Sampling was required for this research as collecting data from the whole population is not possible. Some limits to the research included time and practicability. The study was conducted with the Greater Manchester Local Resilience Forum in England one of the UK's Local Resilience Forums (LRFs). The population is the whole people or phenomena under study (Somekh and Lewin, 2005) while sampling has been defined as "the selection of cases from wider populations" (Bloor, 2006). Tashakkori and Teddlie (2003) provided a comprehensive definition of sampling as "selection of units (for example, events, people, groups, settings, artifacts) in a manner that maximizes the researcher's ability to answer research questions that are set forth in a study".

Sampling techniques are of two types; probability sampling and non-probability sampling (Saunders et al., 2009; Easterby-Smith, 2012). Probability sampling is often associated with quantitative research and employs procedures to ensure that a representative sample is chosen from the population under study. This, in turn, allows the researcher to make generalizations from the sample to the population it represents. In contrast, qualitative researchers use non-probability sampling as it does not require the selection of a large sample and random sampling procedures (Easterby-Smith, 2012). The choice of which technique should be applied depends on the nature of the research.

This research focuses particularly on understanding a current phenomenon in-depth, which is the collaboration among multi-agencies in a risk assessment environment. This research requires participants who have experience and knowledge in multi-agency collaboration in a risk assessment environment. As a result, non-probability sampling is the suitable method for conducting the research (Easterby-Smith, 2012). Abowitz and Toole (2010) emphasized that non-probability sampling methods are very common because approaching individuals can enhance the response values.

As indicated by Saunders et al. (2009), non-probability sampling can be classified into five types: quota sampling, snowball sampling, convenience sampling, purposive sampling and self-selection sampling. Denscombe (2010) explained that purposive sampling is one that is chosen based on the knowledge of a population and the purpose of the study, with the subjects chosen because of certain characteristics. In the case of this research, the subjects needed to have specialized expert knowledge in the field that was under investigation. Furthermore, selecting the purposive sampling technique is important to in terms of the quality of data gathered; therefore, the reliability and competence of the informants must be ensured. According to Bernard (2002) and Lewis et al. (2006), the researcher selects what needs to be identified and seeks out people who are willing to provide the information by the quality of their knowledge or experience.

Therefore, this research adopted the purposive sampling technique, for both the initial capture of the stakeholders' desired characteristics from then semi-structured interviews and then later in the evaluation of the interactive map prototype which utilized a questionnaire survey (made up of open, closed and rating scale questions), observation, and discussion. During the first step, the researcher established a list of respondents who with whom the researcher already had contact and who had experience of collaboration among multi-agencies in the risk assessment environment. In choosing the sample, two principles had to be satisfied by the potential respondents. Firstly, they had to have had experience in multi-agency collaboration in the area of risk assessment environments and, secondly, they had to have worked in the risk assessment area and, therefore, had to had have membership of LRFs. These principles confirmed the validity of the respondents and were followed for both phases of the data collection. For the initial capture of stakeholders' preferred characteristics for the interactive map, the sample involved 16 participants from Category 1 response organizations. All participants at this stage were senior managers (see Table 1 for their profile). Category 1 stakeholders were chosen since they are the ones involved in the risk assessment process within LRFs.

In short, a total of 16 participants were interviewed and their responses recorded to capture the characteristics that would be suitable for an interactive map. These participants were selected on the grounds of their role and experience, so as to provide the highest quality of information possible.

5.6.1.2.1 Semi-structured Interviews with Senior Managers

In this stage of the research, senior managers from Category 1 responders in The Greater Manchester Local Resilience Forum in England were interviewed. The semi-structured interviews were conducted with 16 participants based on their position in the agencies. 14 of the participants gave written feedback. (This written feedback was given by their completing the questionnaire shown in Appendix A, during the interview.) These participants were senior managers and deputy managers of agencies of Category 1 responders in the Greater Manchester Local Resilience Forum, such as the Greater Manchester Police service, the Greater Manchester Fire and Rescue services, the National Health Service, NW Ambulance Service, Greater Manchester local authority, the Environment Agency, Transportation for Greater Manchester and from the UK's central government. Details on the participants are listed in Table 5. 3.

Table 5. 3: Profile of senior managers who undertook the semi-structured interviews

Organization	**Coding**	**Job function**	**Interview** **Greater Manchester Local Resilience Forum (GMLRF) (numbers interviewed)**
Greater Manchester Police service	A1, A2	Strategic commander	2
	A3	Tactical commander	1
Local authority	B1	Strategic commander	1
	B2	Tactical commander	1
The Environment Agency	C1	Strategic commander	1
	C2	Tactical commander	1
National Health Service	D	Strategic commander	1
		Tactical commander	
Greater Manchester Fire and Rescue	E1	Strategic commander	1

service	E2, E3	Tactical commander	2
Transportation for Greater Manchester	F1	Strategic commander	1
	F2	Tactical commander	1
NW Ambulance Service	G1, G2	Tactical commander	2
The UK's central government	H	Advisor	1

As noticed in Table 5.3, Category 2 responders or organisations were not included in the semi-structured interviews because Category 2 organisations are 'co-operating bodies' which are not likely to be involved in the core of planning and risk assessment pre-event, but are more heavily involved in any incident that affects their sector and in a 'supporting' capacity to Category 1 responders (CCA, 2004). In this sense, Category 2 responders have a lesser set of duties as compared to Category 1 responders who were interviewed for this research. Due to the lesser set of duties of Category 2 responders, they are unlikely to engage in the rigorous critical thinking required of the Category 1 responders. So while the collaborative model and the activity theory influenced a consideration for including Category 2 responders, the critical thinking model (which is where prompt and logical ideas for risk assessment is required) helped to limit the semi-structured interview participants to Category 1 responders only.

In this research, the interview method was used to capture user requirements for an interactive map system to support the collaborative risk assessment process and the questions were designed based on these captured requirements. The process utilised is the six-step risk assessment process. The process involves contextualisation to collectively understand the social, natural, infrastructure and the hazard site risks in a local area. Next comes a hazard review to collaboratively identify significant risks, followed by a risk analysis relating to the identification of the likelihood, outcome and impact of local risks. The next stage is risk evaluation, involving the collective identification and prioritisation of local risk hotspots, followed by risk treatment in which team members collaborate to handle the risks they have identified. The final step of the process is monitoring and reviewing, involving the updating, reviewing and maintaining of the information held by the multi-agency teams. The stakeholders' information requirement in this environment is the collection of social, natural, critical infrastructure and hazard site information. This information enables the stakeholders to obtain an overview of the local area risks, its geography, vulnerabilities and population. Furthermore, a small set of questionnaires was used to capture their agreement with the importance of an interactive map for various risk assessment tasks. This constituted the first phase of the data collection. Once the interactive map prototype had been created according to the characteristics identified, then a second phase of data collection began in order to evaluate the system. The following section outlines the method of data collection used in the prototype evaluation.

5.6.1.3 The Questionnaire Survey as a Research Technique for Evaluation

The questionnaire survey technique is an efficient method of data collection from a large sample of respondents (Saunders et al., 2007), in order to obtain information that is difficult to observe or is not readily available in computerized form (Remenyi et al., 1998). Furthermore, Easterby-Smith et al. (2008) described the questionnaire survey technique as a helpful method of collecting data the on the views and behaviour of a large number of people. As indicated by Remenyi (1998), there are two types of questionnaire survey: close-ended (structured) or open-ended (unstructured).

In the second phase of the data collection (the evaluation of the prototype), a scenario was presented to the participants before a workgroup discussion was held in which the subjects talked about the prototype's potential usefulness. A questionnaire survey was selected to follow this discussion, as a means of capturing the opinions of individual group members. The questionnaire utilised open, closed and rating scale questions, and was followed by a workgroup discussion. A detailed description of the evaluation methodology, including a discussion of the choices made in relation to the techniques used, the questions involved, the participants and the procedure is given in Chapter 7.

5.6.2 Research Techniques for Data Analysis

This research used different techniques for the data analysis for the capture of characteristics and for the evaluation of the prototype interactive map. As previously described, the capturing of characteristics involved qualitative data produced from semi-structured interviews. Once this data had been collected, it was analyzed. Yin (2009) identified data analysis as "examining, categorising, tabulating, testing or otherwise recombining evidence, to draw empirical based conclusions". Easterby-Smith et al. (2008) stated that a researcher should be careful in choosing the appropriate technique for analysing data depending on the philosophical and methodological assumptions made in the research design. Furthermore, Easterby-Smith et al. (2008) explained six different methods of analysing data: content analysis, grounded analysis, discourse analysis, narrative analysis, conversation analysis and argument analysis. In grounded analysis, views are determined from the empirical data itself but no pre-determined codes play a role in the analysis while, in content analysis, the researcher classifies structure and ideas that have been decided beforehand by testing the data (Easterby-Smith et al., 2008). The other four techniques are concerned with the 'how' and the 'why' of individuals' language used in a specific social context. The researcher in this study used content analysis techniques to interpret the collected data rigorously in order to identify the characteristics that stakeholders felt would be useful for an interactive map.

The second collection of data in this study came after the prototype had been developed. As previously discussed, this entailed a questionnaire survey which combined open, closed and ratings' scale questions. This provided both quantitative and qualitative data. The results from the rating scale questions were analysed quantitatively, with the maximum, minimum, median and mean average scores analysed. However, this quantitative analysis was supported (and further discussion upon the data gained) by the content analysis of the open and closed questions, and by group discussion. More detail on this is given in Chapter 8.

5.6.3 Validity and Reliability

The selection of the research strategies used for the data collection for this research were all based on a careful consideration of their impact on the validity and reliability of the research results. As explained by Collis and Hussey (2009), validity is the extent to which a research result reflects the actual scenario or issues that influence the subject being studied. While several factors such as biases, the nature of data collection techniques, and participants' emotional views on the subject matter can influence the validity of data (Denscombe, 2008), Yin (2009) argued that validity of results can be tested especially when using subjective methods such as interviews. Validity can be tested using construct, internal and external validity and reliability (Yin, 2009).

The construct validity adopts the use of multiple sources of evidence to establish a chain of evidence and case study or past incidents to review the information provided (May, 2011). This was done in this research by using the mixed methods approach which ensures that the limitation of one data collection technique is mitigated by using another complementary data collection technique, hence the use of a questionnaire, semi-structured interviews and multiple sources for the secondary data that are discussed in the literature review and in the chapters preceding this chapter. Internal validity, as explained by Yin (2009), relates to the ability to create a link between credible causal relationships and ensuring that the influence of theory is consistent. Within this research, the methods, sources and choice of participants were based on their relevance and ability to provide information that relates to the research area. Furthermore, the influence of the activity theory, the collaboration model and critical thinking were stressed throughout this research and assisted in helping to determine the extent to which the information and the methods were valid.

External validity, on the other hand, relates to being able to determine the domain in which the research results fits into and the context for which the information, knowledge and theory generated can be generalised (Yin, 2009). In this case, the research domain was disaster management, with an emphasis on the planning phase where risk assessment is required and necessary. This infers that any information provided outside this context was irrelevant to this research area and was either discarded or treated as information for awareness purposes only. All this scrutiny helped to ensure that the researcher's and participants' biases and personal views did not overshadow the focus of this research.

Reliability entails the level to which the information provided by people and research results is credible and can be ascertained (Bryman, 2008). Reliability in this research focused strictly on ensuring that the appropriate research participants were selected through the sampling process, that references consulted were within published materials and that the information provided by participants was verified in the preparedness phase and in the disaster management system as a whole. Reliability was also enhanced through the triangulation of data and the results (May, 2011). Ascertaining the participants' information utilising existing knowledge within this field helped to increase the reliability and validity of the results as well as identifying the new or emerging orientations in risk assessment. All these were managed by the researcher in accordance with the ethics' requirements for this research.

5.7 Research Ethical Considerations

The researcher considered all the ethical considerations in order to conduct this research. In the invitation letter, it was made clear that the data given were confidential and would not be distributed to third parties, and that anonymity was assured. Moreover, as previously mentioned, all the participants received a full explanation of the research, and it was ensured that they gave full, informed consent. Furthermore, in the evaluation of the prototype, participants were given the chance to express their opinions in a group discussion but also via the written questionnaire, meaning that they did not have to express certain opinions in front of their colleagues and partners if they did not wish to.

5.8 Summary

This chapter has outlined how this research is based on an interpretivist, idealist philosophy and takes a value-laden approach, concerned as it is with the actions, beliefs and needs of people, specifically in multi-agency risk assessment activities. Due to the IT nature of this research, the design science in information systems (IS) approach was chosen as the approach. In the first phase of the data collection, the researcher employed semi-structured, face-to-face interviews as the main method of data collection to capture the characteristics of the system. Then, in the second phase, a questionnaire survey (made up of open, closed and rating scale questions), observation and discussions were used to evaluate the interactive map prototype. This combination of different techniques was used in this study to minimize the weaknesses of each individual technique and to satisfy the requirements for research validity and reliability.

Semi-structured interviews were preferred when in the process of capturing the characteristics for the interactive map, because this technique produces in-depth data while maintaining a structure within the interview process. This structure was required in order to ensure that the questions being asked were linked to the stages of the risk assessment process. Stakeholder senior managers involved in disaster management in a Greater Manchester Local Resilience Forum in England were interviewed. The semi-structured interviews were conducted with 16 participants based on their position in 8 different agencies. Content analysis was used to analyse the data from these interviews and to define the user requirements for the interactive map system. Once a platform had been built based on these requirements, its prototype was analysed using a methodology that used quantitative analysis supported by the content analysis of the qualitative data produced from discussions, and from the open and close questions in the feedback questionnaires. Throughout this process, participants gave full, informed consent and their anonymity was ensured. The next chapter presents the design of the questionnaire and the analysis of the outcomes.

Chapter 6 – User and system requirements

6.1 Introduction

Following the inductive approach this research first conducted interviews with senior managers of category 1 responders in The Greater Manchester Local Resilience Forum (LRF) to capture the requirements for the multi-agency collaboration platform. This chapter summarises the design of the questionnaire and presents the analysis of the outcome. This chapter analyzing

6.2 Method Used to Collect Data

For this research, 16 senior managers of Category 1 responders in The Greater Manchester Local Resilience Forum (LRF) were interviewed and the responses recorded. 14 participants gave written feedback via the questionnaire that was presented at the same time as the verbal questions. They comprised senior managers from the police service, fire and rescue service, ambulance service, National Health Service, the local authority, the Environment Agency and Transport for Greater Manchester. Senior managers were used as the subjects as they occupy positions at a strategic and tactical level.

6.3 Process of Data Collection

Initial invitations were sent to the respondents. These invitations explained the research's aim and objectives and included a copy of the structure of the interview. Participants were then given a face-to-face presentation about the purpose of this research. The use of an interactive map in other applications such as urban regeneration was presented and this was used to inspire participants about the potential of an interactive map in risk assessment. Face-to-face, semi-structured interviews with the participants were then held. This format of interviews (which Robson (2002) described as a mix of structured and unstructured interviews) is where the questions are presented in sequence and the period of time taken to respond can be changed in each topic during the interview. In addition, an advantage of semi-structured or open-ended interviews is that richer data can be obtained, as the interviewees provide much more detailed information and insight in their responses (Easterby-Smith et al., 2008).

These interviews were recorded and transcribed by the researcher, with the length of each interview varying between 90 and 120 minutes. The interviews were rich in information and participants offered various views. The researcher applied the content analysis approach for the analysis of the data.

6.4 Questionnaire Design

To ensure that the data received corresponded to the risk assessment process, the steps of the risk assessment process were utilised in the designing of the questions. The questionnaire utilized for the semi-structured interviews was based on the six-step risk assessment process proposed in the Australian/New Zealand Emergency Preparedness report (based on the standards used in Australia and New Zealand) and widely recognized as being of good practice (Guidance on Part 1 of the Civil Contingency Act, 2004). The six steps of the risk assessment process are illustrated in Figure 6. 1 below.

Figure 6. 1: The Six-step risk assessment process (Cabinet Office 2012, Local responder risk assessment of Emergency Preparedness).

A number of questions were created, corresponding to each step in the risk assessment process. In the contextualization stage, questions were designed to capture the kinds of information that would be most useful in order to build up a common understanding of the local risk context. Moreover, participants were asked about how the social, natural, infrastructure and hazard site risks in the local area could be combined and visualized most effectively and whether this would improve their understanding of local risk. Questions relating to the hazard review stage focused on participants' perceptions of how useful an interactive map would be in helping users to capture past experience, intelligence and research data and in communicating this to other team members during hazard review meetings with the goal of collectively identifying significant local risks.

Risk analysis questions were designed to capture participants' views on the usefulness of an interactive map in visualizing cascading effects to simulate the impacts of hazards. Furthermore, the questionnaire aimed to capture the kinds of simulation data, historical data and experiences that participants felt to be useful. A question relating to the risk evaluation stage was designed to capture whether participants felt that representing risk ratings on an interactive map could help agencies to have a holistic view of hazards. A question connected to the risk treatment stage asked what the participants' views were on the visualizing required and on the current capabilities of the map and whether this would help them to understand the capability gaps and address the additional treatments required to close the capability gaps and manage the risks more effectively. Additional questions aimed at discovering what types of capabilities participants wanted to be visualized and how these could be useful. The final part of the questionnaire investigated the overall usefulness of an interactive map in helping multi-agency teams to collaboratively update, review and maintain information regarding local risks in order to continuously improve risk management strategies and to build resilient communities. In the following section the questions derived from the risk assessment process were used to elicit data via the semi-structured interviews with Category 1 responders.

6.5 Analysis of the Data

<u>Step 1: Contextualisation</u>

The Emergency Preparedness report suggests that Category 1 responders should describe the characteristics of the local area that will influence the likelihood and impact of an emergency in the community. The following questions have been defined to explore if an interactive spatial map could help Category 1 responders build up a common understanding of the local risk context.

Q1.1: The ability to explore various **social intelligence** (such as the demographic, ethnic and social composition of the community, the geographical distribution, identification of vulnerable groups, the level of community resilience) in an interactive spatial map could help Category 1 responders establish a collective understanding of the local risk level. What additional social data is important for you to be displayed on the map? How could such social data exploration on an interactive map be useful for multi-agency teams?

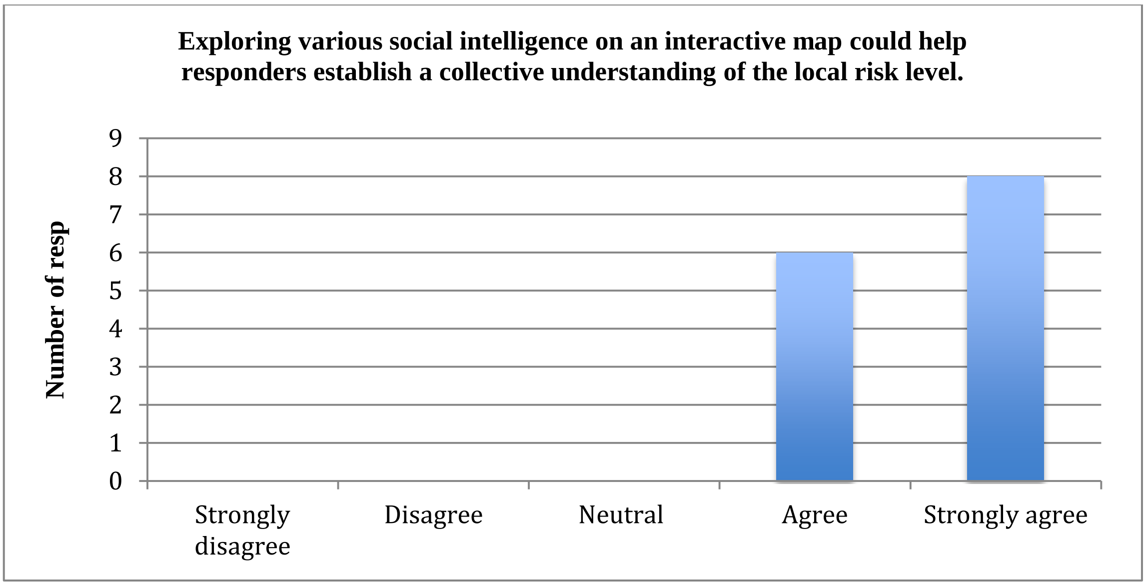


Figure 6. 2: Respondents' rating on the contextualisation of the social information

With regard to the contextualisation of social information, the overall results highlight that the majority of the respondents strongly agreed that the ability to explore various social intelligence could help Category 1 responders establish a collective understanding of the local risk level. The remaining respondents agreed that social information is important in the understanding of the local risks. Most participants stated that the ability to identify and locate vulnerable people was the most important aspect of contextualising social information.

In emergency management, risk is a function of hazard and vulnerability. The term 'vulnerability' has a variable nature as it depends on the ability of a person to save himself/herself in the presence of a risk. It also varies depending on the size and type of the hazard, as indicated by all the respondents. Most of the respondents noted that it is important to identify the vulnerable, to know their location and take into account the cultural characteristics of the community to which they belong. Interviewees B1 and B2 observed that data sets throw up demographics that can help understand the risk posed, the potential consequences, and the impact of that risk locally, but that then this would also start to inform the response. There was agreement among the respondents from the different agencies that knowing and understanding demographic data and displaying it on an interactive map is useful for planning and evacuation in order to build resilience and mitigate risk. According to Interviewees C1 and C2, the identification of vulnerable groups and the level of local resilience is very important in understanding the ability to respond during an incident and is valuable in the planning stage.

While some respondents categorised the vulnerable according to the community to which they belong, others categorised them according to their needs. Interviewees A1 and A2 referred to vulnerable people those having language or communication problems or healthcare and mobility needs. The 'vulnerable' are also referred to as either communities or as individuals. Interviewee B1 noted that the mapping of demographic data, for example in Greater Manchester, helped to identify which communities have a community plan in place and those who need a specific response plan to be set. Interviewee B1 also indicated that demographic data would also help to know how to communicate and engage with vulnerable groups, whether communities or individuals, to inform and warn them. Interviewees B1 and B2, as well as interviewees A1 and A2, stated that some communities have their own networks in order to pass messages on to one another. Interviewees B1, B2 and D referred to communities such as the Chinese and the Somali communities as self-helping and self-mobilising communities.

The data on vulnerable individuals and groups helped to identify the people at risk. According to Interviewee E1, using flooding as an example, such people can be graded in terms of their ability to evacuate or the reasons why they may, or may not, be able to do so. The aim is to understand the size of the evacuation support required (such as medical support) and to where they might need to be evacuated.

Interviewees A1 and A2, as well as C1 and C2, described the vulnerable in terms of old age or young age as well as those having physical disability. However, Interviewees B1, B2 and D argued that the elderly or disabled might not be vulnerable if they have contingency plans or a support package. Both of these sets of interviewees referred to social relationships, such as neighbours or networks with other members of the community.

According to Interviewee D, social demographics would help to identify the location of vulnerable communities and individuals, but that vulnerability would be slightly different within different scenarios. Interviewee B noted that vulnerability depends on the size of the incident, the threat and the nature of the emergency.

The vulnerability or resilience of a student population depends on the type of risk according to Interviewees B1 and B2. Such a category is more resourceful and more resilient in the case of a flood but in the case of pandemic flu, if the disease targets the 20 years' old male age group (which was one of the demographics) and some of them were living alone away from some of their normal support networks, then that could make them more vulnerable.

With regard to the interface of the interactive map and the use of the interactive environment, Interviewees G1 and G2 emphasized the benefits of an interactive environment by comparing the display of data on the interactive map with a simple spreadsheet. Interviewees C1 and C2 specified that, in a flood situation, they would certainly want population densities to be put on such a map and overlaid on top of that, an indication of the vulnerable. According to interviewees C1 and C2, the display of data via the layers or simulation would help in planning an evacuation in case there is a threat. In the case of a flood in an area with a nearby COMAH site there could be a need for an evacuation (of vulnerable communities) and, therefore, interviewees stated that it definitely helped to see the scenario visually. Similarly, these participants noted that, for example in the case of an incident involving a release of chemicals near the Lowry complex in Manchester, it would be extremely valuable if the members of the LRF were able to see it in the form of a simulation.

Interviewees E1 and E2 added that, in the case of a flood or a potential gas leak, it would be useful mapping out the number of people that may need to be evacuated. This would help them plan and decide as to where they would evacuate the people, the routes that they may need to keep open or closed, the transportation methods and the holding centres. According to Interviewees F1 and F2, knowing the demographics of the users of public transport would help them to identify any weaknesses in services. Knowing the demographics of people who are going to different events such as music concerts or football matches would also help in evacuation plans. Other interviewees underlined the problem of capturing data of a changing nature, such as the daytime and nighttime populations of specific sites; for example, interviewee A3 referred to the changing data on population in different parts of the city center or Piccadilly Gardens during the course of a day and the difficulties in capturing these differences in order to plan and evacuate if there is a risk.

To sum up, characteristics have been derived as requirements from the data analysis with regard to the Contextualisation of social information. The following have been identified as the main characteristics.

Social information
• **Demographics** 1. Population densities 2. Population changes daytime/night-time • **Community** 1. Ethnic communities who are not well integrated with society generally and have language difficulties 2. A transient population (travellers' communities, students) • **Mobility needs** 1. Elderly people 2. People with disabilities 3. Families with children (infants) 4. Pregnant ladies • **Health care needs** 1. Serious medical needs (requiring special medical equipment for evacuation) 2. Specific types of illnesses (needs special procedure for evacuation) 3. Those with chronic health conditions • **Building hosting vulnerable people** 1. Hospices 2. Schools

Q1.2: The ability to explore the **local environment** and understand the local vulnerabilities and characteristics of the space (urban, rural, mixed), scientific sites, etc. on an interactive spatial map could help Category 1 responders receive a better collective understanding of the likelihood of, and the impact of, an emergency in the community. What additional data on the local environment would be of importance for you to be displayed on the map? In your view, how could such an interactive exploration of the environment on an interactive spatial map be useful for multi-agency teams?

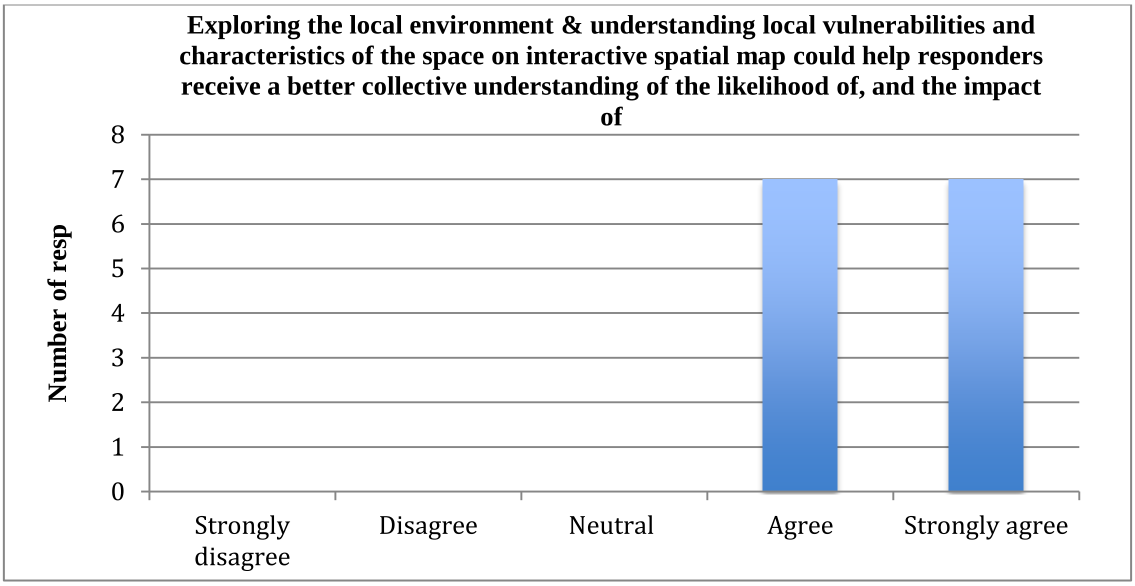


Figure 6. 3: Respondents' rating on the contextualisation of the local environment

With regard to the contextualisation of the local environment, the results indicated that all the respondents strongly agreed or agreed that the ability to explore the local environment and understand the local vulnerabilities and characteristics of the space (urban, rural, mixed, scientific sites, etc.) on an interactive spatial map could help Category 1 responders receive a better collective understanding of the likelihood of, and the impact of, an emergency in the community. Participants identified a number of features that would be valuable to include on an interactive map, agreeing that workplaces and residences should be mapped but also that sites which could have knock on effects if they were affected by a disaster (such as COMAH sites, laboratories and cooling towers) would also prove useful to include.

As far as the mapping of data relating to the impact of hazards on the local environment was concerned, the respondents from the different agencies mentioned a variety of buildings that needed to be mapped and displayed on the interactive map. These ranged from residential and business properties to university labs, hospitals and COMAH sites. They also emphasized the usefulness of the interactive map environment in bringing together the various stakeholders involved in the multi-agency risk assessment.

The display of the mapped data could help the multi-agency teams (Category 1 responders) to understand the risks posed and enable them to use such data in planning and mitigation. According to E2 and E3, a flood map showing the properties that are at risk overlaid with information on vulnerable groups, critical infrastructure and COMAH sites would aid decision-making before and during an incident and would then be used for planning and mitigation purposes (evacuation). They found displayed or visualized date useful not only for COMAH sites which impact on the environment, but also for presenting the features within the location around COMAH sites, such as rivers. Other interviewees also emphasized the value of visualisation of interdependencies and aggregated risks. According to the interviewees, it is useful to know the location of a hospital and to see whether there are any COMAH sites next to it. Interviewees B1 and B2 noted that the mapping of buildings etc. helped to identify any high-risk areas if flooding occurs. This information can be overlaid by any suitable data, for example about any chemical works nearby. The participants also wanted to see what else might be affected by a river flooding (such as a reservoir) and the effect of any aggregated risks caused by such an event on the population.

Interviewees B1 and B2 referred to the geographic nature of risks. According to these participants, knowing the geographic nature of a risk might help in improving warning and informing, in encouraging members of a community to warn their family, friends and neighbours. Interviewees C1 and C2 noted that data about the topography of an area in the case of a flood, when the water level rises to a certain point, will enable the responders to know exactly which houses are going to be flooded. This will help in dealing with flash floods or surface water floods when it is difficult to predict as to where the water will flow. Having information about the local topography would help responders in putting in certain flood barriers and in knowing exactly how many homes could be protected. This view was shared by interviewees A1 and A2 who described the limits of their existing mapping techniques compared to what they expected from an interactive map.

A1 and A2 stated if would be useful to show different types of accommodation on the interactive map (such as bungalows, traditional two-storey houses and flats) as, in the case of a flood, knowing which accommodation had more than one level (i.e. not just ground level) would be beneficial for evacuation planning.

Providing accurate data about buildings as well as population data (on one layer), with another layer containing information about vulnerable people, can help set priorities for evacuations. From such information the responders can identify those who need to be got out first because they are going to take longer to be evacuated. In a flood scenario if the vulnerable are to be evacuated first, then others can then be left in houses on the upper floors.

Displaying information in layers would enable agencies to share the data on the layers within the collaborative environment. Interviewees C1 and C2 stated that the value of this platform would be to bring together the local authority, planners and ‘blue light’ organisations in the planning stage, and in planning about COMAH sites, industry sites, waste sites, and so on. Interviewees noted that, within a collaborative environment, some agencies would know who holds what information required and thus it could be visualized and included in their planning; for example, the Environment Agency would be able to access the police’s information about traffic congestion, and thus plan their activities to avoid congested areas.

For interviewees G1 and G2, knowing the location of biological and nuclear facilities would help in understanding the risks posed by them in cases of an emergency and thus planning could be undertaken taking this in account. For such types of sites, the risk is low but the impact would be huge. In the case of concerns with regard to biological or biometric type labs, interviewees A1 and A2 noted that local authorities would have information about the location of these sites, because the authority grants them licenses. At present, such information is provided, generally, only if the multi-agency teams ask for it. [Interviewees B1 and B2 explained that obtaining informational data about sites such as cooling towers (which use water to reduce heat in buildings and which, if badly managed, can be breeding grounds for legionella which causes Legionnaire’s disease) can help manage risks.

To sum up, characteristics were derived as requirements from the data analysis with regard to the Contextualisation of natural environment. The following have been identified as the main characteristics.

Natural environment
• Reservoirs • Topography • Area with risks of land slide • Rivers • National parks • Forests • Animal sanctuaries

Q1.3: The ability to explore the **local infrastructure** (transport, utilities, businesses), the critical supply network and critical services (telecommunication hubs, health, finance, etc.) on an interactive spatial map could help Category 1 responders receive a better understanding of the likelihood and impact of an emergency in the community. What additional data on the infrastructure is of importance for you to be displayed on the map? In your view, how could such an interactive exploration of the local infrastructure be useful for multi-agency teams?

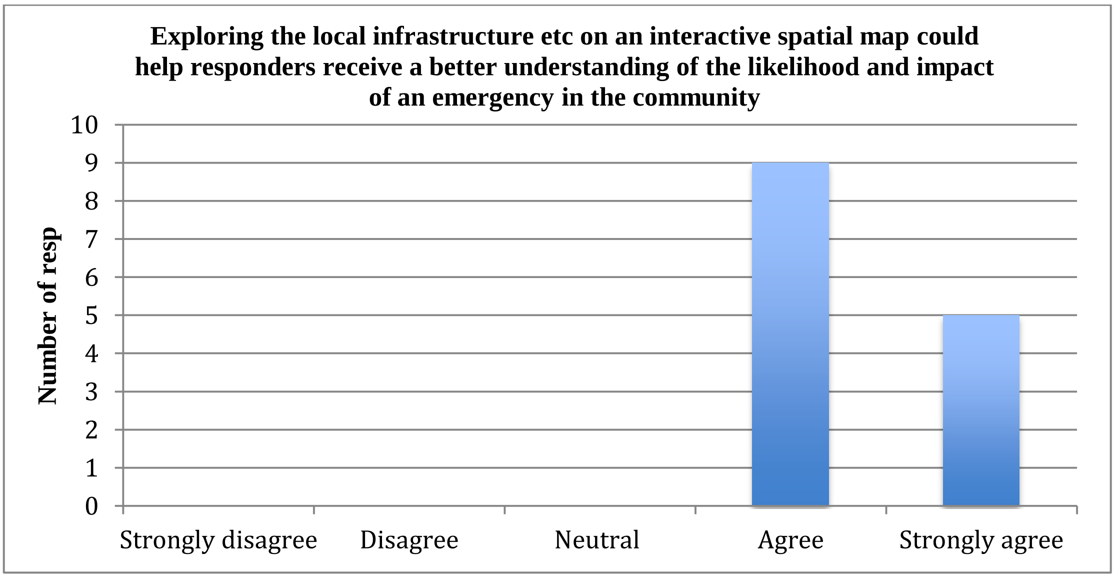


Figure 6. 4: Respondents' rating on the contextualisation of the local infrastructure

With regard to the contextualisation of the local infrastructure, the majority of the respondents agreed that an ability to explore the local infrastructure (transport, utilities, businesses), the critical supply network and critical services (telecommunication hubs, health, finance, etc.) on an interactive spatial map could help Category 1 responders receive a better understanding of the likelihood and impact of an emergency in the community. Other respondents (namely, 5 of the interviewees) strongly agreed with this statement.

The infrastructure information that needs to be mapped and visualised on an interactive map, as mentioned by most of the respondents, relates to utility services etc. such as gas, electricity, water, telecommunications, bridges, schools and hospitals. The respondents emphasised the impact of a risk (that could be caused by these elements) to the population such as failures of substations and damage to gas pipes attached to bridges. They also stressed the interdependencies between various risks. Most of them referred to flooding as the major hazard that poses risk for the population and the local infrastructure.

According to interviewees A1 and A2, infrastructure sites are particularly valuable to map in terms of flooding in order to know what could be damaged or destroyed by a flood. If an electricity substation is about to get flooded or it is predicted that it will be flooded, prioritisation has to be undertaken based on how many people would be affected. There is also a need to know the interdependencies of a risk; for instance, Electricity North West would be asked how many people and what key infrastructure would be affected by a substation failure as this would affect homes and also hospitals and transport. Interviewee E1 felt that it is important to understand the interdependency in order to mitigate the risk or to build resilience. If a substation supplies a hospital that thus is very dependent on that substation's electricity, then it might become a priority because it is not ideal for the hospital to run on generators, in the case of an emergency, for a significant length of time.

Participants commonly suggested that all substations should be mapped. Interviewees E2 and E3 observed that substations are important regardless of where they are located and commented that "it could be something as mundane as a substation in a field in the middle of nowhere but if that gets flooded and taken out of operation, you could be losing power to 50,000 houses". They recommended that the interdependencies between substations should also be identified. Interviewees G1 and G2 explained that knowing the location of all the substations in an area would help to identify the impact in that area. It might be, should some be lost in a disaster, that each of them just causes the loss of power to several thousand buildings; it might be, however, that a particular substation on the map is the feeder for all of them, so if that one is lost the consequences are much greater. This is where the industry experts' knowledge is needed in the risk assessment.

Interviewees B1 and B2 put forward another example of interdependency, citing the collapse of a bridge and the possible effect of this on the utility services. They suggested that a bridge collapse would make a utility network particularly vulnerable (as utility providers have to ensure a way of getting cables and pipes over rivers and, therefore, bridges present an obvious way of doing this and thus are generally used for this purpose). Interviewee E1 also observed that, in general, utility supplies become more vulnerable when they are above ground rather than underground. This interviewee showed the importance of mapping telephone exchanges and communication networks so as to raise the issue of business continuity in relation to the building of resilience. This participant noted that any hazard that would remove an area's communication network would have a large knock-on impact for businesses. Interviewee A3 noted that agencies' focus is not only on responding to an incident but also on building resiliency by understanding the potential impacts of hazards.

As an example of risks that can occur that can affect local infrastructure, E1 mentioned a fire in Manchester that had broken out under a BT building. This affected the telephone exchange and wiped out a significant proportion of central Manchester communications, including the emergency service number 999. This is an example of the kind of infrastructural risk that should be displayed on an interactive map, as it shows that a relatively small incident can have very significant impacts.

All respondents agreed that an understanding and visualisation of interdependencies and aggregated risks helps in planning and in agreeing evacuation plans between agencies. According to interviewees B1 and B2, for a better understanding of such interdependencies, there may be a need for gap analysis in order to know where the gaps and vulnerabilities are which, in turn, will make it possible to plan for them and to try and mitigate them. According to interviewee E1, an understanding of utilities services and supply networks would definitely help with undertaking exercises and realistic modelling and would really help, particularly at a tactical and strategic level. Visualisation of utilities services and supply networks would have a big impact on the undertaking of exercises and testing plans.

Data displayed on the interactive map is useful for communication and collaboration as well as decision-making and collective planning. For Interviewee D, an interactive meeting with the other agencies, with all the representatives being able to see the same visualization, would improve collaborative decision-making and communication. Interviewee D even suggested that the simulation technique could incorporate aspects of computer gaming and emphasized its benefit for the multi-agency collaboration. He stated that simulation means that "you can explore the area where there are floods, for instance, schools, and can actually see it unfolding and I think that has a value for collaborative decision-making and planning for evacuation. The relationship between the agencies is collaborative rather than confrontational and adversarial".

With regard to decision-making and collective planning, interviewees C1 and C2 observed the potential use of the interactive map platform in terms of collective planning for risks. When it is known that an incident has occurred, they can position equipment in the most useful locations and can make decisions effectively. The participants suggested that, for high risk sites, they could look at the site, take into account factors such as wind direction, and quickly know whether their first activity should be to close certain roads.

Interviewee G1 observed that the health infrastructure is critical in all types of incidents. The interviewee mentioned local GPs, nursing homes and hospitals and utilising mapping data on them. This participant also emphasized the visual pattern of what is in an area as well as working collaboratively and gave an example of a road closure that may block the entrance of a hospital. G1 described how police could close a particular road, without anticipating that it would prevent access to a key healthcare site such as a hospital. The participant suggested that, with better collaboration and an interactive map upon which to look, such a situation would be less likely to arise because agencies would be alerted to such a fact.

To sum up, characteristics were derived as requirements from the data analysis with regard to the Contextualisation of infrastructure. The following have been identified as the main characteristics.

Infrastructure
• **Utility services (hubs)** 1. Electrical Substations (Electricity supply networks, electricity transformers) 2. Telecom substation (Telecom supply networks, Green boxes, Mobile phone towers and masts, Premises of data hubs of communications' centres) 3. Gas substations (Gas supply networks) 4. Water distribution points (Water supply networks) 5. Pumping stations (Waste water systems, drainage systems) • **Transport** 1. Bridges 2. Tram networks 3. Rail networks 4. Road networks (existing & highways, major roads) 5. Bus stations (bus stops) 6. Traffic lights 7. Airports • **Buildings** 1. Major financial institutions 2. Shopping centres 3. Football grounds 4. Health buildings; Local GPs, Walk-in clinics, Doctors, Nursing homes & Hospitals, Pharmacists 5. Residential houses; Bungalows, Traditional two storey houses & Flats 6. Buildings of interest; Police, Ambulance & Fire stations 7. Business premises

8. Heritage buildings & sites 9. Density of housing 10. Universities

Q1.4: The ability to explore **potential hazardous** sites and their relationships to communities or sensitive environmental sites on an interactive spatial map could help multi-agencies to understand the likelihood of, and the impact of, hazardous events in the local area. What hazardous sites are of importance for you to be displayed on the map? In your view, how could such an interactive exploration of hazardous sites be useful for multi-agency teams?

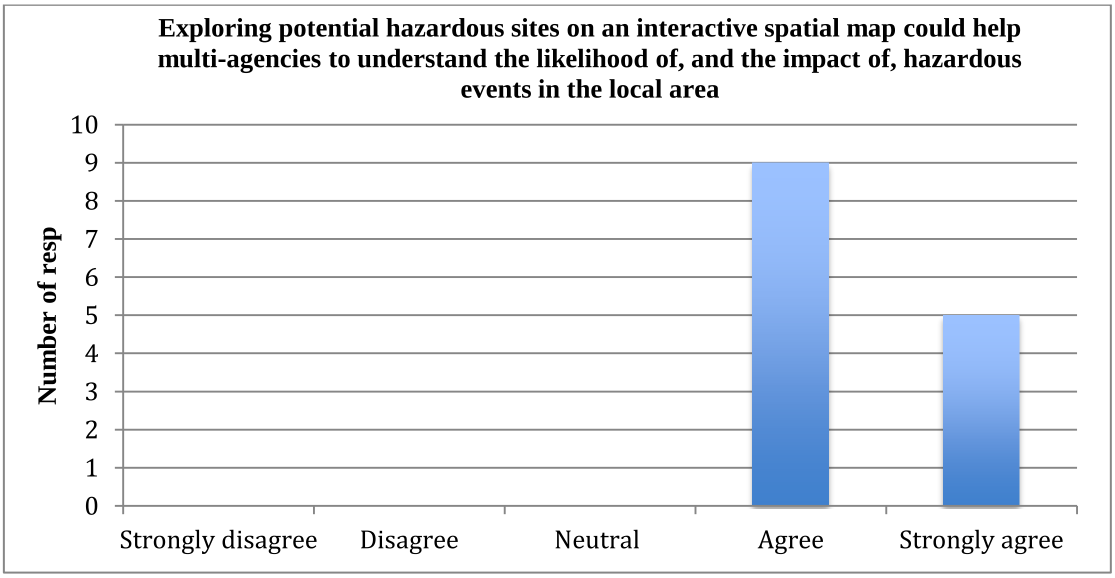


Figure 6. 5: Respondents' rating on the contextualisation of the hazardous sites

With regard to the contextualisation of hazardous sites, all the respondents strongly agreed or agreed that the ability to explore potential hazardous sites and their relationships to communities or sensitive environmental sites on an interactive spatial map could help multi-agencies to understand the likelihood of, and the impact of, hazardous events in the local area. From the interviews it emerged that participants felt that it would be most useful to include COMAH, chemical and waste sites.

There was agreement amongst all the respondents that a knowledge and understanding of any chemicals stored and their potential effects on the population would be useful in assessing risk and in taking preventive safety measures and in setting in place specific plans for mitigation. Some participants also referred to wildfires, forest fires or fires within oil rich sites. All the interviewees emphasised the usefulness of the interactive map in planning, sharing data between agencies and collaborative working.

Interviewees B1 and B2 thought that all COMAH sites should be mapped, not just the top-tier ones which are likely to cause the biggest emergencies. The example given in the interview was the Buncefield fire in December 2005 in the Hertfordshire Oil Storage Terminal, UK. This oil storage facility was not a top-tier COMAH site, but was just below the top-tier level. According to Interviewees C1 and C2, knowing the location of a waste site, and what surrounds it, is useful in the planning stages. They suggested that it would be very beneficial to produce a 'COMAH plan' with the local authority to create plans of action in the case of certain incidents. Interviewee E1 referred to building the resilience of communities that are within the area that surround a COMAH site. In such a case, the relevant agencies should communicate to people within this area regularly, so residents know what to do if an alarm goes off on the COMAH site. The same view was expressed by an interviewee who noted that members of public living close to facilities like chemical plants should have knowledge concerning possible emergencies and what to do if they occur.

Interviewees G1 and G2 noted that reservoir inundation is a sensitive threat and may be the most difficult threat to handle. Thus reservoir inundation planning is undertaken in advance in case such a threat occurs. Interviewees E2 and E3, considering flooding or forest fires, also stated that they had started putting measures in place to deal with such possibilities, building such likelihoods into their risk assessment so as to identify the risks. They were also putting in intervention measures in the form of a plan, so that if something does happen, they will know what their procedure is in order to deal with such a possibility.

All the interviewees would recommend the use of an interactive map and data sharing within the collective working offered by an interactive map to members of the LRF from different agencies. A1 and A2 raised again the issue of licenses, which is information that only local authorities and the Environment Agency hold at present. Other agencies can only obtain such information if they ask for it. They referred to a fire at a recycling plant in Stockport in August 2012. The plant affected had licences issued by the Environment Agency. They suggested that, although the fire service was aware of the risks at that plant none of the other agencies were particularly aware of the risks (other than the Environment Agency). This, the participants argued, revealed many issues as a result of what was being stored at the plant, issues that some of the agencies had not previously been aware of. Individual agencies were aware of them but, as a collective, they were not.

Therefore, this showed that sometimes information is held by individual agencies but is not shared at a collective level, and that sometimes, therefore, it is only when they have to collaborate because of an incident that has occurred that all the agencies actually understand what is there at the incident site.

Displaying data about hazard sites and the risk they may pose for the environment is useful in assessing and understanding the aggregated risks as well as in the planning. Interviewees A1 and A2 noted that risk assessment covers the risks posed by COMAH sites and the impact on the water supply. Interviewee A3 explained that if there is a release of a chemical from a chemical site and that the wind is blowing, an interactive map could show them where it would go and its potential impact (as examples, it might mean the closure of a motorway and agencies would have to think about the risk of the chemical getting into the water supply).

Interviewees C1 and C2 noted if they had a process that covered everything, such as the interactive map platform, they could feed the data in and produce something that everyone from all the agencies could understand. They would then be able to reassess the risks. They could prioritise the risks based on economic, environmental, public safety and other key considerations. Interviewees C1 and C2 gave an example of a scenario in which all the agencies could be involved. "There was a fire near London which I believe closed the M1 for two days. It was from a waste fire so there were impacts on people from the smoke and the dust. There was transport disruption which led to major economic impacts because one of the arterial roads was closed. The cost to UK PLC rose by the hour. Environmentally, there was firewater run off into the river potentially polluting the river. There was a substation nearby which looked likely to be taken out". Such an incident in the example above made the participants think about potential fire sites that could cause problems either by damaging substations, by firewater running off and damaging the environment, by train travel disruption and by major road blockages, and so on. Interviewees G1 and G2 in their comments gave an example of a visualization of the Trafford Centre in Manchester where they would be reliant upon the fire service to give them a layout plan of the building.

According to Interviewees G1 and G2, the interactive map platform would be useful as it allows them to identify all the vulnerable areas. They considered it as one tool that would suits all the agencies, designed specifically with multi-agency collaboration in mind. They felt that the platform could take on board all the relevant information from all the relevant agencies that would be needed when dealing with a particular type of hazard. At present, according to these interviewees, sometimes some data is not shared openly, but rather has to be requested.

To sum up, characteristics were derived as requirements from the data analysis with regard to the Contextualisation of hazardous sites. The following have been identified as the main characteristics.

Hazardous sites
• Recycling plants • Waste disposal sites • Chemical sites (Chemical storage sites, Chemical factories, Oil rich sites) • Oil refineries • High pressure gas lines • University labs; Biological, Biometric & Radiological risks • Nuclear facilities • Cooling towers (Legionella) • Dam failures

Q1.5: The ability to visualize a combination of risks **(social, environmental, infrastructure, hazardous sites**) in an interactive map could help Category 1 responders build up an integrated view of the local risk context. What combinations of risks would be useful to be shown on the map?

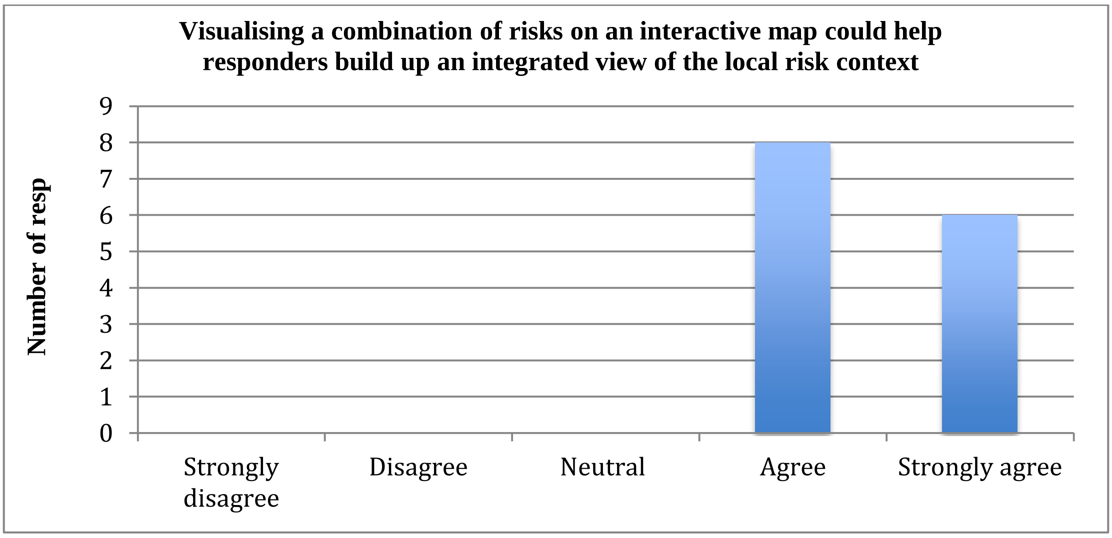


Figure 6. 6: Respondents' rating on the contextualisation of the combination of risks (social, environmental, infrastructure, hazardous sites)

With regard to the contextualisation of a combination of risks, more than half of the respondents agreed that an ability to visualize a combination of risks (social, environmental, infrastructure, hazardous sites) in an interactive map could help Category 1 responders build up an integrated view of the local risk context. The other respondents, which represented less than half of the interviewees, strongly agreed with this statement.

All the respondents emphasised the importance of the interactive map for the display of various data and indicated how they would want the layers to be shown on the map. All interviewees agreed that it is useful to have a combination of risks shown, such as chemical releases, flooding, fire and social unrest (i.e. riots) affecting sites, critical infrastructure and the population. All agencies would like to be able to see various data displayed all at once; the layering of different kinds of information emerged as being particularly desirable. According to Interviewees C1 and C2 such an environment would allow for sharing of data a lot more freely.

Interviewees A1 and A2 noted that they definitely needed to overlay layers on other layers; for instance, in the case of a chemical release, they wanted to have information on the chemical sites and the demographics in the areas around them. For Interviewees C1 and C2, various levels on the spatial map would also be extremely useful; for example, a flood map with properties that are at risk which was overlaid with information on vulnerable groups, critical infrastructure and COMAH sites would aid decision-making both prior to an incident for planning purposes and during an incident. According to Interviewees G1 and G2, the more information that the platform could provide about risks, the more they could put resources into dealing with, and mitigating, those risks.

The participants' responses also suggested that the interactive map platform would also be helpful in planning and prioritising. G1 and G2 suggested that if data about national infrastructure is displayed, then this would help in the understanding of knock-on effects which would be useful in the planning stage to mitigate impacts. According to B1 and B2, it is vital to have this platform which enables all the agencies to understand the impact on the human population, the natural environment, other infrastructure and on cascading risks posed by things that happen simultaneously. B1 and B2 referred to aggregated risks which involve river flooding and failure of reservoir dams and electricity substations.

Interviewees A1 and A2 gave an example to explain how the overlaid data about sites and demographics could help in evacuation plans. If there was a chemical fire incident in Trafford Park and the wind was blowing towards Sale, they argued that it would be very useful to know what the population of Sale is, which parts of it could be under threat and how long it would take to evacuate people. This social information could be connected with environmental information such as wind speed. Demographics' information, they argued, is always useful when one is looking at an evacuation of any sort, be it because of a chemical cloud or an explosion or a flood. All this information helps to understand the potential impact and how quickly they can get people out. Interviewees C1 and C2, as well as E1, emphasised the usefulness of the interactive map for the display of multiple risks and complex situations. Interviewees C1 and C2 observed that the mind can only hold information on a certain number of risks, but the platform might show a couple of keys areas upon which it is necessary to focus amongst the multiple risks in a particular area. Accordingly, this would help practitioners to have a broader view. With regard to prioritisation, Interviewees F1 and F2 emphasised the importance of information on hazards as these can have a massive impact on social, economic and heath aspects and which could, for example, assist them in making decisions about prioritising roads which lead to facilities such as schools, hospitals and police stations.

Step 2: Hazard Review

Hazards that present significant risks are identified on the basis of experience, research or other information. These hazards are shared and discussed at LRF meetings with a view to agreeing a list of hazards that need to be assessed. The following questions have been defined to explore if an interactive spatial map could help Category 1 responders capture experience, intelligence and research data and communicate them to others during hazard review meetings.

Q2.1: Utilising your past experience, an interactive map with appropriate graphical illustrations could be used to represent the likelihood of, and the impact of, hazards. What type of experiences would you like to present on the interactive map to enhance communication and discussion during hazard review meetings?

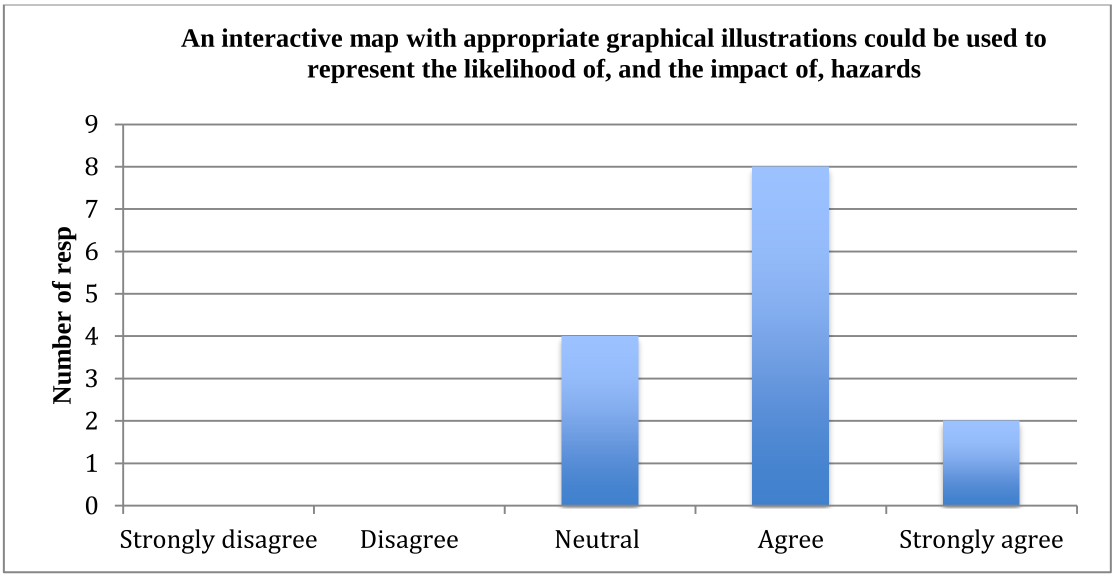


Figure 6. 7: Respondents' rating, utilizing past experience, on the usefulness of an interactive map in the Hazard Review step

The majority of the participants agreed that experience should be included in an interactive map, with 2 strongly agreeing and 4 remaining neutral on the fact that it is useful. Historical data emerged as a popular element of an interactive map reality platform. This was noted by a number of participants who tended to suggest that such data would help users learn from past experiences of similar emergencies. G1 and G2 described using past experience of planning as a foundation. Interviewees A1 and A2 suggested that historical data about past flu pandemics should be included on the interactive map. B1 and B2 pointed to a similar level of interest in Legionella outbreaks. Similarly, A3 called for the inclusion of historical records relating to the floods of the River Irwell. The participants noted that including such records would help users learn from the actions undertaken and the problems encountered in past emergencies. E2 and E3 wanted to see detailed information on past experiences, such as casualty numbers, incident size and where the problem began. A1 and A2 noted that historical data from other parts of the country should be included, in order to learn from the actions and experiences of others. They suggested that data on the impact of previous severe flooding in Somerset would be useful.

Participants who called for the inclusion of historical data generally linked it to simulation. A1 and A2 commented that information about previous flu outbreaks, for example in London, would help them to model the impact that similar pandemics would have in Manchester. B1 and B2 also expressed concern over flu pandemics and commented that the extent of such an impact within Greater Manchester is difficult to predict. The use of past experience in simulating events was also outlined by H, who suggested that the sharing of previous experiences of crowd problems, fires and industrial accidents and their impacts would be useful learning and simulation tools. Moreover, E2 and E3 argued that historical details help give a clear picture about current priorities and hazard identification.

Suggestions as to how this experience should be presented pointed to the information being presented visually. C1 and C2 suggested that a map, which could be viewed by everyone, would be helpful, as did E1, E2 and E3 in their interviews. Similarly, G1 and G2 stated that maps could show the development of, and hotspots involved in, previous emergency experiences. They suggested that this would be a very useful tool for a multi-agency team.

Q2.2: An interactive map with appropriate graphical illustrations could be used as a medium to present the likelihood of, and the impact of, hazards derived from research data. What type of research data would you like to present on the interactive map to enhance communication and discussion during hazard review meetings? Comment on other types of data that could be beneficial within an interactive map.

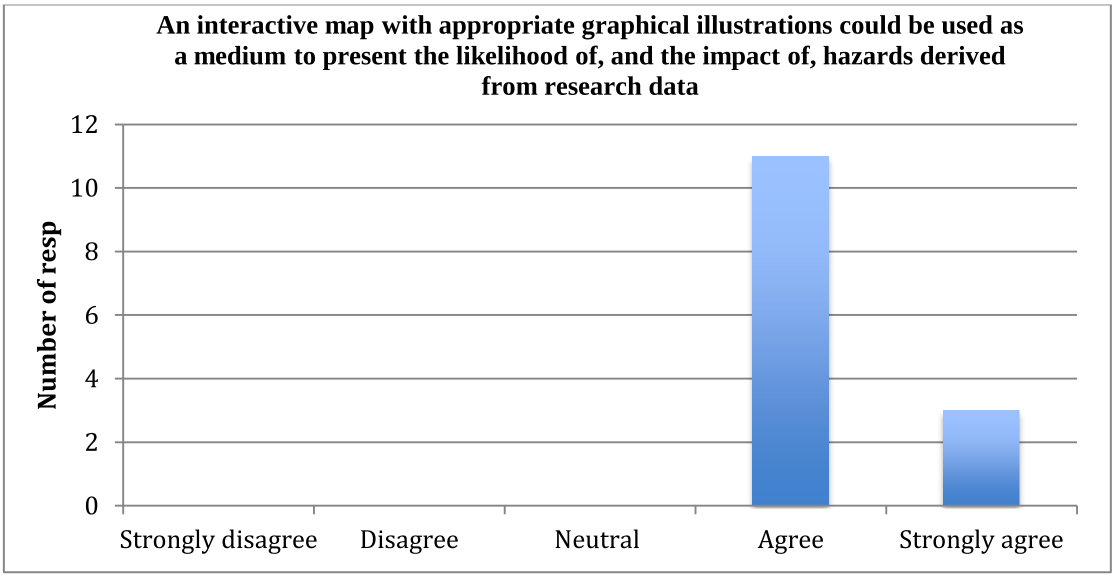


Figure 6. 8: Respondents' rating on the use of research data in the interactive map in the Hazard Review step

Research data was commonly suggested as being a useful tool that should be included in a multi-agency platform. Majority of all the participants agreed with his point, while a three strongly agreed. Participant H described the importance of being able to access and bring together large amounts of knowledge from research. Moreover, C1 and C2 stressed the importance of taking an evidence-based approach to a disaster response, rather than relying on intuition and gut feeling. They noted that understanding the likelihood of events has to be a scientific process. The research data that participants would like to see fall into three categories – social, environmental and industrial.

Interviewees described social research into the behaviour of people (specifically crowds) during an emergency as being useful to show on an interactive map platform. E2 and E3 expressed interest in work being undertaken by Manchester University into crowd dynamics. Research into the behaviour and movement of large groups of people during an incident would help responders factor in the potentially unpredictable behaviour of the pubic during their hazard review. A3 supported this idea, suggesting that predicting how people will react is equally important as what is going to happen. B1 and B2 also called for the inclusion of research, but from a legislative perspective. They suggested that having access to information about the regulatory regime that governs an area would be useful.

Many interviewees described a need for environmental research to be included in a platform. Phenomena such as wildfire (suggested by E1, E2 and E3), climate and weather (E1, G1 and G2), flooding (E2 and E3) and volcanic ash (A1 and A2) emerged from the interviews as being areas of research to which participants would like to have access. E2 and E3 noted that research from Australia into wildfire can be applied to the hazards faced in moorland areas, while E1, G1 and G2 noted the usefulness of data relating to weather and heat wave cycles.

Finally, research into the nature of emergencies at industrial sites was also suggested as being useful. E2 and E3 suggested that research into impacts of emergencies at COMAH sites and chemical plants would be beneficial to access as part of a multi-agency platform.

Q2.3: The use of an interactive map, integrated with hazard information, could help members of the Risk Assessment Working Group (RAWG) and the Local Resilience Forum (LRF) make careful judgments on which hazards should be included in further assessment. How?

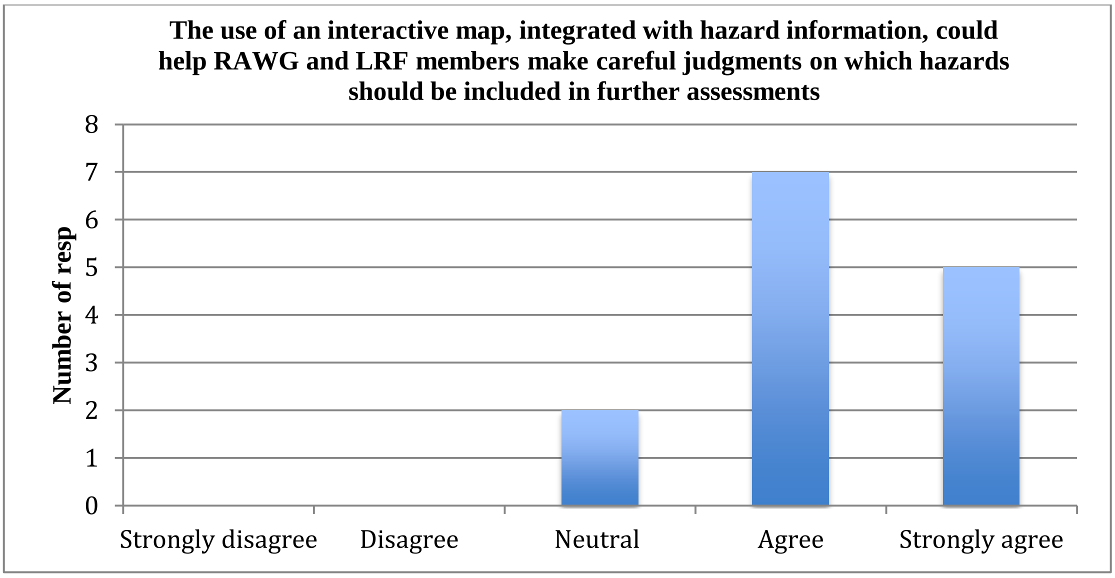


Figure 6. 9: Respondents' rating on the use of an interactive map, integrated with hazard information in the Hazard Review step

Interviewees were in favour of an interactive map integrated with hazard information. Half of participants suggested agreement while a third suggested strong agreement and 2 remained neutral. There were four main reasons for this support. Firstly, participants felt that such a platform would help them prioritise risks more effectively and efficiently. C1 and C2 felt that it would make the prioritising of risks quicker. Similarly, D suggested that an interactive, integrated platform would help quantify the risks that should be given priority.

Secondly, participants felt that a platform with an interactive map, combined with information about hazards, would improve the quality of decisions made by multi-agency teams. E1 noted that, by giving users access to quality information, the platform will help them make better decisions, while E2 and E3 argued that a platform would increase the amount of information available to multi-agency teams and thus improve their judgements.

Thirdly, interviewees suggested that a platform like this would enhance judgements because it would allow users to connect and contextualise hazards and impacts; for example, E1 argued that an integrated platform would allow users to see the wider picture and not only see hazards in isolation. F1 and F2 also supported this view, suggesting that the platform would benefit them by bringing different scenarios together.

Finally, the visual nature of an interactive map and integrated hazard information emerged as something that participants supported. G1 and G2 argued that demonstrating data in map form would be preferable to data displayed in spreadsheet form, while B1 and B2 suggested that displaying information visually helps multi-agency teams reach a common understanding.

<u>Step 3: Risk Analysis</u>

The purpose of this step is to consider the likelihood of, and the outcome and impact of, a hazard. The Local Risk Assessment Guidance (LRAG) from central government should provide a basis for this work, but the local knowledge available within the Risk Assessment Working Group (RWAG) and other local organisations should allow the RAWG to elaborate on the assessment. The purpose of this section is to explore how the collaboration of Category 1 responders could be enhanced in elaborating this assessment.

Q3.1: The use of an interactive spatial map to present the local risks' context (social, infrastructure, environmental, hazardous sites) and the outcome of a hazard (derived from computer simulation or experience) could help Category 1 responders to collectively elaborate the assessment of a hazard and measure its impact. What types of simulation data, historical data and experiences could be useful for visualizing on the interactive map and why? How could the integration of the local risks' context and the outcome of hazards be useful?

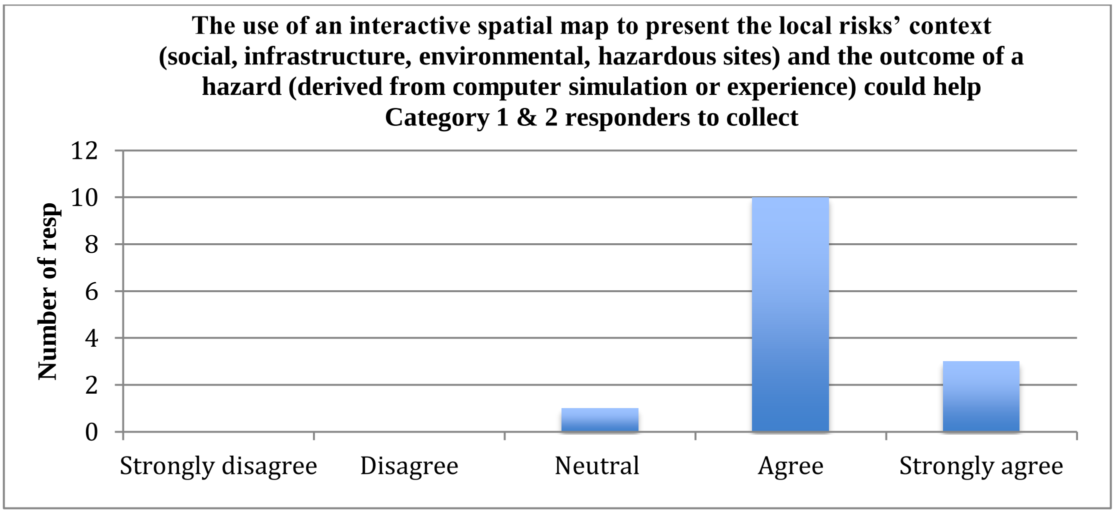


Figure 6. 10: Respondents' rating on the use of an interactive map to present the local risks' context in risk analysis step

Interviewees identified numerous kinds of data that they would like to have access to as part of an interactive map. The majority said they agreed with an interactive map showing social, infrastructure and environmental data as well as the location of hazard sites. 3 participants went further and strongly agreed, while 1 remained neutral. Interviewees also explained why this data would be helpful in risk analysis. Participants gave a range of responses about what data they would like to see. Areas at high and medium risk of flooding (A3, C1 and C2, E1, E2 and E3 and H), data about weather phenomena such as wind direction and speed, rainfall and snowfall (A1 and A2, A3, B1 and B2) and an analysis of threats to key infrastructure like bridges, reservoirs, dams, railways and roads (B1 and B2, E1, E2 and E3) all emerged as the kinds of data that participants would like to be provided with in an interactive platform.

Data relating to economic impact was something else that the interviewees would like to see. C1 and C2 suggested that being able to consider the economic impact that hazards present would be useful for them. They used the example of the average cost of a flooded house as an example of financial data that would help in risk analysis. Similarly, D called for the consideration of the financial aspects of risk analysis, while F1 and F2 talked of the need for modelling the impact, for example, that road closures have on businesses in a given area. Another notable type of data that emerged from the interviews was Internet access by the public in different areas. A1 and A2 suggested that the public's access to the Internet can influence how well agencies are able to inform and warn the residents about emergencies. This has a knock-on effect for risk analysis, because it influences how the public will respond.

Broadly, interviewees give similar responses as to how these kinds of data would help them in risk analysis. A3 suggested that such data would help multi-agency teams identify areas that are at risk when this risk is high enough to be obvious. The identification of wider, knock-on effects also emerged from the interviews. G1 and G2 described the importance of analysing the risks of a number of areas, while F1 and F2 stressed the need to anticipate the impact that an incident can have on the whole transport network. Similarly, A3 described the knock-on effects that snow can have on areas in which the population is not accustomed to snow. Most broadly, B1 and B2 suggested that this sort of data will, generally, help planners to have a greater understanding of the areas that they are analysing and the populations within them.

Q3.2: The use of an interactive spatial map to present cascading effects would help Category 1 responders to build up a broader perspective of the outcome of hazards and their impact. What types of cascading effects of hazards will be useful?

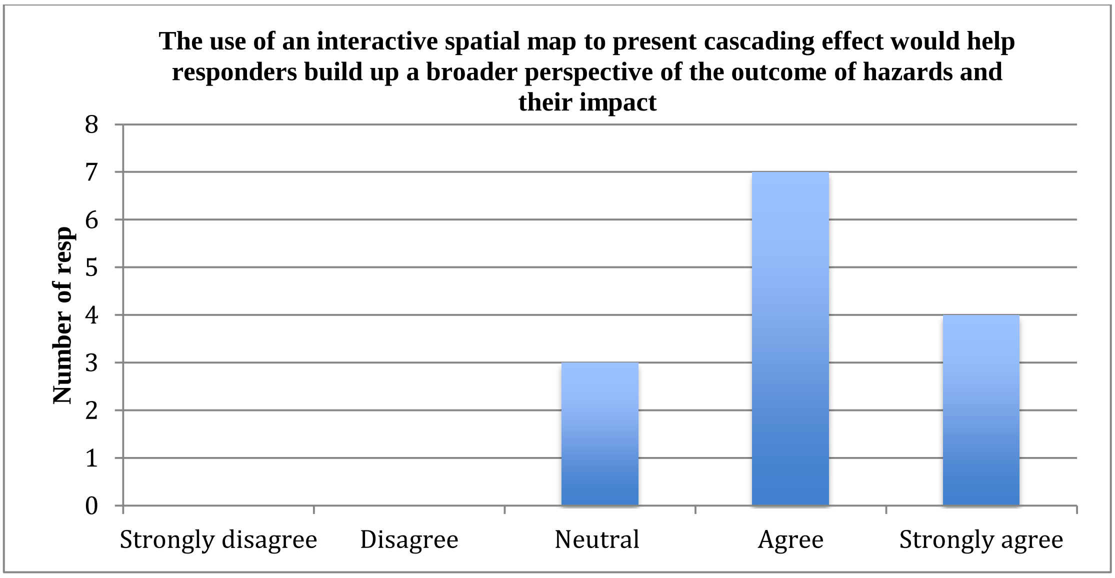


Figure 6. 11: Respondents' rating on the use of an interactive map to present cascading effects in the risk analysis step

Half of the interviewees agreed that an interactive map would be useful in modelling cascading effects, while the remaining participants either strongly agreed or were neutral. Participants outlined the cascading effects that they would find useful. Half agreed that these should be modelled on an interactive platform, with fewer participants strongly agreeing and a minority remaining neutral. In general, the cascading effects that the participants outlined related to the wider impact that a disaster of one kind could have on the human population.

Interviewees B1 and B2 and C1 and C2 explained how they would discover the cascading effects of an environmental disaster like a flood on the wider human population. Both sets of participants noted the importance of knowing the location of substations in relation to areas of flooding, because if flooding causes the loss of a substation then the electricity supply to thousands of households can be cut off. C1 and C2 noted the cascading effect that this loss of electricity would have, not only on individuals, but also on businesses and, therefore, the local economy. Most interviewees had an interest in the cascading impact of river and reservoir flooding (A1 and A2, A3, B1 and B2, C1 and C2 and D).

The knock-on effects of chemical fires were also noted in more than one interview. B1 and B2 suggested that information about the population close to a chemical fire would be useful. They argued that if a chemical fire released different gases into the atmosphere, then knowing the percentage of the local population that is affected by respiratory illnesses would be important. E2 and E3 also express interested in having access to the cascading impact of chemical fires.

Other participants showed interest in the cascading effects that would impact on the population of an area in different ways. D, for example, explained the importance of knowing the cascading effects experienced by a lack in the supply of electricity. D noted how a electricity power shortage means that people cannot heat their homes in winter and would be unable to withdraw money from ATMs and, as a result, be unable to refuel their cars to go out and purchase a generator. Interest in cascading public health effects was also expressed by B1 and B2 who noted the public health hazard posed by wastewater and sewage in the event of a flood. E2 and E3 expressed a similar interest in this area.

Other cascading effects identified included the effects that an outbreak of an illness would have on essential services (F1 and F2), the effects that snow would have on traffic and transport (E1, A3, F1 and F2) and the knock-on effects that terrorist strikes would have on public buildings and infrastructure (A1 and A2, C1 and C2).

Overall, participants expressed a strong desire for information regarding cascading effects and their impact on the population of an area. However, E1 argued that modelling cascading effects can be both a positive and negative process. This participant pointed out that it can be natural, when considering cascading effects, to become distracted by hypothetical issues and move too far away from the core problem and its impact. This suggests that an interactive platform should balance the need to consider cascading effects with the risk that a user may lose sight of the initial problem.

Step 4: Risk Evaluation

The production of a risk matrix is an essential part of the risk assessment process. Four risks' ratings (very high, high, medium and low) are used to indicate the risk level.

Q4.1: The representation of risks' ratings on an interactive map could help agencies to have a holistic view of hazards in their local areas. What additional information on the interactive map could be useful at the risk evaluation stage?

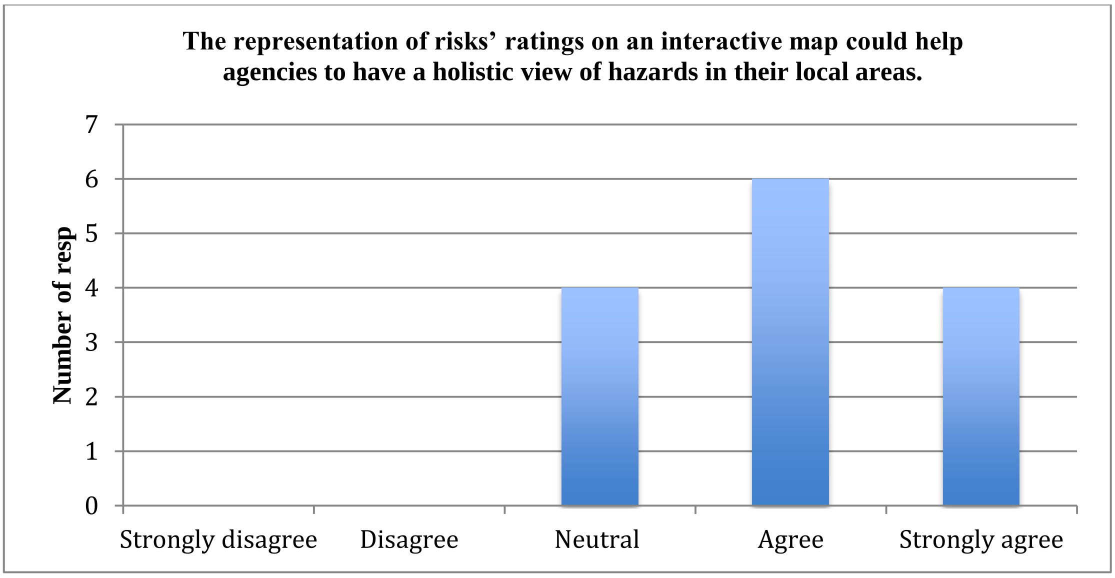


Figure 6. 12: Respondents' rating on the use of risks' ratings on an interactive map in the Risk Evaluation step

The most popular response to the representation of risk ratings on an interactive map was agreement. 4 further participants strongly agreed, while 4 others remained neutral. Participants' responses were mixed on the nature of an interactive map to be used in risk evaluation. The majority agreed or strongly agreed, but a similar number remained neutral. For instance, A1 and A2 reported that it was difficult for them to envisage, but H suggested that it could be useful for LRFs in their risk evaluation.

Most participants stressed the need for a map to represent complicated risk evaluation data visually. B1 and B2 suggested that the map should present colour-coded areas according to their risk assessment. D argued that the map should model risk hotspots. C1 and C2 described how an interactive map would be most useful if it allowed users to see the risks of events occurring at the same time. That said, the map would have to allow users to take different viewpoints, and perhaps change the map according to different variables.

Some participants were keen to stress that an interactive map would have to be flexible and allow for risks to be layered and also differentiated depending on the situation. For instance, B1 and B2 described how a substation may be evaluated and displayed on a map as being at low risk. However, the substation could be in a larger area of higher risk. Therefore, an interactive map would have to display both of these aspects and allow users to zoom in and out. Similarly, E1 noted that an interactive map would have to be able to display changes to risks depending on other factors, such as time of year. E1 gave the example of an area that could be evaluated as being at high risk of flooding, but only at certain times of the year. This would then effect the evaluation of the risk of the wider area. E1 argued that an interactive map would, therefore, have to account for this, perhaps allowing the user to move between different views.

There was agreement between the participants on how risk evaluation should be based on priorities. D suggested that risks should be evaluated and weighted according to their potential environmental, economic and social impacts. E1 described approaching risk evaluation with the intention of doing the best for the most people. F1 and F2 echoed this principle.

Step 5: Risk Treatment

Risk treatment has a number of stages: assess the type and extent of the capabilities required to respond to hazards; identify capabilities in place, consider the capability gaps and the extent of the risk; rate the risk priority; identify additional treatments required to close the capability gaps and manage the risks more effectively, and identify whose responsibility it is to provide treatment, etc.

Q5.1: The visualisation of the capabilities required and the capabilities in place on an interactive map would help agencies to collectively understand the capability gaps and address the additional treatments required to close the capability gaps and manage the risks more effectively. What types of capabilities should be modelled and visualized? How could the modelling and visualization of capability data on an interactive map be useful at the risk treatment stage?

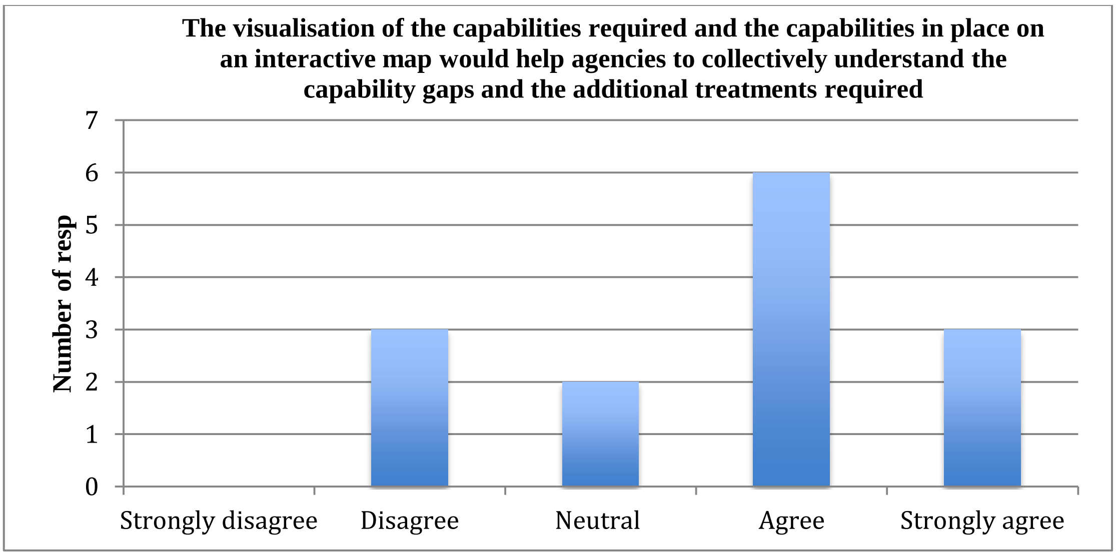


Figure 6. 13: Respondents' rating on the use of the visualisation of the capabilities required and the capabilities in place on an interactive map in the risk treatment step

The most common response to this question was agreement, but the same number of participants who expressed strong agreement, namely 3, expressed disagreement. The remaining 2 participants remained neutral. The need for the sharing information relating to agencies' capabilities was a clear theme in the interviews. C1 and C2 described a clear need for the sharing of information relating to capabilities to be improved, so that multi-agency teams have a clearer understanding of their collective capability. Moreover, E2 and E3 pointed out the government's promotion of inter-operability.

However, many interviewees stressed how difficult achieving this would be. A1 and A2 suggested that mapping capabilities at a local level would not give a comprehensive understanding because some disasters receive a national response. H agreed with this assessment, while A3 pointed out how keeping track of capabilities is made difficult because of how dynamic and changeable these capabilities are. A3 gave the example of how the numbers of staff available to an agency depends on the time of day. B1 and B2 were more optimistic, noting that simple data like the numbers of fire, police and ambulance stations in an area is quite simple to map. However, they noted that more specific data on capability (and how it might be impacted upon by a disaster) is more difficult to map.

This said, some interviewees reported having quite clear ideas about how capabilities can be mapped. C1 and C2 described the benefits they would see from a multi-layered map showing the different levels of equipment and staff held by each agency in different areas. They stated that the benefits would come from being able to see which agency has what equipment in which areas, and then being able to move such equipment and staff into other areas. F1 and F2 also favoured the use of layered map. There was some evidence that some agencies already have a good grasp of their own capabilities. For instance, G1 and G2 observed that the fire, police and ambulance services have a working knowledge of where their capabilities are at any one time. They suggested that this information could be shared with other agencies. Moreover, A3 noted that agencies can use self-assessment frameworks to map their own capabilities and noted that the fire service has a strong understanding of its own capabilities. Ultimately, it seems that, as C1 and C2 argued, mapping the capabilities of multiple agencies could be achieved with collaboration.

Step 6: Monitoring and Reviewing

This stage implies that risks should be monitored continuously and that the previous steps (1 -5) should be repeated when new risks are identified.

Q6.1: The availability of intelligence collected from Step 1 to Step 5 within an interactive map in an integrated form could help Category 1 responders to continuously improve their risks' management strategy and build resilient communities.

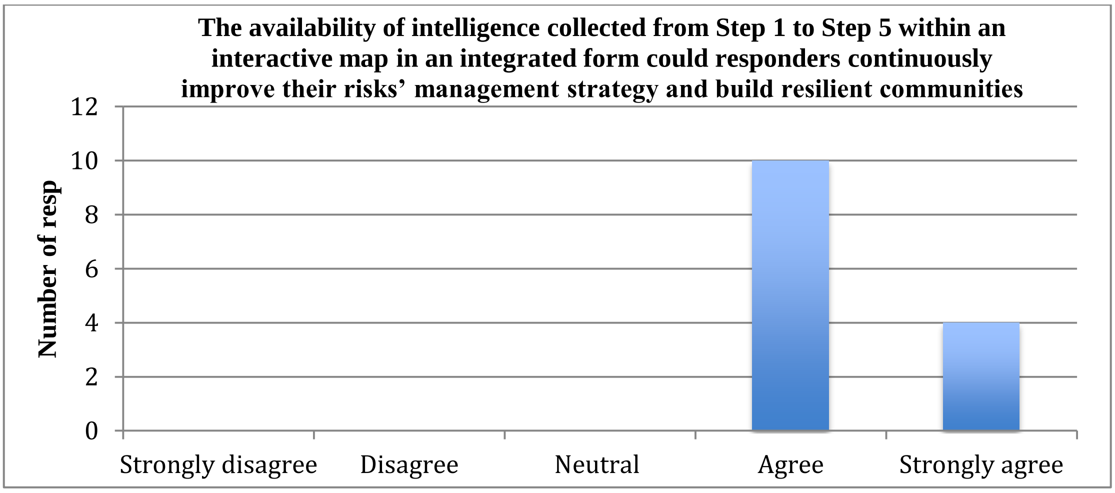


Figure 6. 14: Respondents' rating on the importance of intelligence collected from Step 1 to Step 5 within an interactive map in an integrated form in the Monitoring and Reviewing step

All participants either agreed or strongly agreed with the idea that an interactive map would help with the ongoing monitoring of risks. There was broad support among interviewees for the creation of an interactive, integrated map. A1 and A2, A3 and H all responded favourably to this idea.

More specific input came from the other participants. B1 and B2 brought up the importance of security for such a platform, noting that if such comprehensive data were brought together into a single platform, then it would be vital that it did not become available to the wrong users. Many participants (B1 and B2, C1 and C2, D, E2 and E3) stressed the need for such a system to be properly updated, reviewed and maintained if it is to have longevity. The value of having a visual, interactive platform was asserted by C1 and C2 and D. C1 and C2 noted how having access to visual information helped with understanding and D suggested that an interactive environment supports communication between multiple users. B1 and B2, D, G1 and G2 all pointed to the usefulness of having a comprehensive collection of data brought into one place.

Q6.2: Having understood the risks, how do you check if you are prepared for disaster?

A number of participants (C1 and C2, E2 and E3 and H) stated that risk assessment discussions were important in checking their preparedness, while D noted the importance of using past experiences in assessing preparedness. Review and undertaking exercises were identified most commonly by the participants when they described checking their preparedness. A3 described a process of planning, undertaking exercises and then checking this against real world experience. After mentioning undertaking exercises, A3 also outlined the role of reflection in checking preparedness. This interviewee suggested that there are two tiers of reflection. The first is assessing how well teams performed from an operational perspective. Did they, for example, know their roles and work well together? The second tier relates to the performance of the tactics that were used. Did, for example, their flood plans work? A3 suggested that both tiers are important in checking preparedness.

Other participants also mentioned undertaking exercises. A1 and A2 asserted that the most common form of undertaking exercises was 'tabletop' which is an office-based simulation of an emergency. The participants mentioned the live undertaking of exercising, with staff on the ground. This, they stated, is a much more expensive activity and, therefore, happens less often than tabletop exercises. B1 and B2 also described using tabletop exercises to test their preparedness. They noted that this can involve putting different groups through the same scenario to test differences in performance. E1 also noted that there is an annual cycle of reviewing risks and of undertaking exercising. As with the previous participants, E1 stated that undertaking exercising is often table top because it is impractical to run live exercises on large numbers of different hazards.

6.6 User requirements

The user requirements that emerged from the interviews with the members of the multi-agency team can be categorised in order to define some of the characteristics of the collaborative environment for risk assessment in disaster management. The information required by the interviewees can be presented under four main themes: Social (S), Natural (N), Critical infrastructure (CI) and Hazard sites (HS). These themes need to be plotted on a map and visualised by the stakeholders. This interactive map environment would enhance stakeholders' decision-making by giving an overview of the area that they wish to concentrate on, including the area's natural geography, its vulnerabilities, critical infrastructure and the location of its hazards. This information is classified into:

- (S) Social Information relating to the human population of an area and its vulnerabilities - the vulnerability of people, demographics, safety and welfare.
- (N) Natural Information relating to the natural environment of an area and its vulnerabilities - environmental, ecological, natural resources.
- (CI) Critical Infrastructure – Information about the location and nature of key transport, communication and utilities in an area - buildings, community infrastructure, substations, utilities and rural life, heritage buildings & sites.
- (HS) Hazard sites - information relating to the location and nature of sites in an area that present a hazard - COMAH sites, flood, forest fire, pandemic.

Table 6. 1 below presents a detailed list of information that should be considered. The first column presents aspects of social information, the second column presents aspects of the natural environment, the third column presents elements of critical infrastructure and the fourth column displays possible hazardous sites. This information is intended to be comprehensive, but not exhaustive; more aspects could be added.

Table 6. 1: Defining the characteristics of the collaborative environment for risk assessment in disaster management that are required within an interactive map

Social information	Natural Environment	Infrastructure	Hazardous Sites
• **Demographics** 3. Population densities 4. Population changes daytime/nighttime • **Community** 3. Ethnic communities who are not well integrated with society generally and have language difficulties 4. A transient population (travellers' communities, students) • **Mobility needs** 5. Elderly people	• Reservoirs • Topography • Area with risks of land slide • Rivers • National parks • Forests • Animal sanctuaries	• **Utility services (hubs)** 6. Electrical Substations (Electricity supply networks, electricity transformers) 7. Telecom substation (Telecom supply networks, Green boxes, Mobile phone towers and masts, Premises of data hubs of communications' centres) 8. Gas substations (Gas supply	• Recycling plants • Waste disposal sites • Chemical sites (Chemical storage sites, Chemical factories, Oil rich sites) • Oil refineries • High pressure gas lines • University labs; Biological, Biometric & Radiological risks • Nuclear facilities • Cooling towers (Legionella) • Dam failures

6. People with disabilities 7. Families with children (infants) 8. Pregnant ladies • **Health care needs** 4. Serious medical needs (requiring special medical equipment for evacuation) 5. Specific types of illnesses (needs special procedure for evacuation) 6. Those with chronic health conditions • **Building hosting vulnerable people** 3. Hospices 4. Schools		networks) 9. Water distribution points (Water supply networks) 10. Pumping stations (Waste water systems, drainage systems) • **Transport** 8. Bridges 9. Tram networks 10. Rail networks 11. Road networks (existing & highways, major roads) 12. Bus stations (bus stops) 13. Traffic lights 14. Airports • **Buildings** 11. Major financial institutions 12. Shopping centres 13. Football grounds 14. Health buildings; Local GPs, Walk-in clinics, Doctors, Nursing homes & hospitals, Pharmacists 15. Residential houses; Bungalows, Traditional two storey houses & Flats 16. Buildings of interest; Police, Ambulance & Fire stations 17. Business premises 18. Heritage buildings & sites 19. Density of housing 20. Universities	

6.7 Summary

This chapter has shown the process by which the characteristics of an interactive map that can enhance multi-agency collaboration in the risk assessment process were captured from stakeholders. Semi-structured interviews were conducted with stakeholders based on a questionnaire which utilised questions relating to each of the six stages of the risk assessment process in the Emergency Preparedness report (Guidance on Part 1 of the Civil Contingency Act, 2004). These face-to-face interviews were recorded and transcribed before being analysed according to content analysis techniques. The visualisation of various kinds of social, natural environment, critical infrastructure and hazardous sites' information (presented in the Table above) emerged as the characteristics that stakeholders require for an interactive map system to enhance their collaboration in risk assessment activities. In the next chapter, the design and implementation of the collaborative risk assessment environment is presented.

Chapter 7 – Design and implementation of the collaborative risk assessment environment

7.1 Introduction

This chapter presents the design of the collaborative risk assessment environment based on the requirements that emerged from the literature review and from the interviews with the stakeholders. The goal of this chapter is to provide a conceptual framework which supports multi-agency collaboration in risk assessment activities. This framework consists of four views (Information view, Process/Activity view, User Interface view and Team Member view) each of which are described in-depth in this chapter, after an initial discussion of the two frameworks for describing system architectures which underpin this study's framework.

7.2 System Architecture Frameworks

In recent years, Enterprise Architecture (EA) has become the established approach for managing organizations' information systems and business processes (Franke et al., 2009). EA can help an organization increase its effectiveness, efficiency, agility and stability via the information it collects (Van der Raadt, 2010). It is widely known as an essential mechanism in management, as it enhances collaboration within an organization. It is now implemented in private and voluntary sector organizations, including humanitarian relief agencies and public services such as the US Federal Emergency Management Agency (FEMA) (Hause, 2010). As indicated by Hause (2010), the most popular EA frameworks are The Open Group Architecture Framework (TOGAF) and the Federal Enterprise Architecture Framework (FEAF). These were both designed to improve the collaboration, performance, planning and implementation of complex systems. As a result, most EA frameworks have accepted the practice of using several architectural layers and views to build their architecture system (Schekkerman, 2004; Tang et al., 2004). Furthermore, The Collaboration Oriented Architectures (COA) suggests that this approach supports collaboration through the design of system architecture. This is achieved by using an architecture view of the principal components that can be used to describe the concept (Jericho Forum, 2008). The COA framework has been put forward by The Open Group (OG) to allow computer scientists to describe their framework using a set of views.

7.2.1 TOGAF & COA

TOGAF is an architecture framework that enables someone to design, evaluate and build the appropriate and right architecture for his or her organisation. It also enables an organisation to develop, maintain and employ enterprise architecture. Additionally, TOGAF has an open character; it pays attention to organisational commitment while other frameworks focus on the architecture itself and prescribe what to do. Producing an architecture is not the ultimate goal of TOGAF; it rather focuses on how an organisation benefits from the architecture (Van den Bent et al., 2007). TOGAF is based on highlighting 'the central role of organisation' (Desfray & Raymond, 2014). Desfray & Raymond, (2014) argued that TOGAF deals with subjects such as the collaboration between different people involved in enterprise architecture. Collaboration is based on an organised process wherein communication plays a crucial role. There should be an understanding of the targets and the aim of the enterprise architecture (Desfray & Raymond, 2014).

The TOGAF features that this study has adopted are those relating to the study aim, the organisational commitment, the collaboration of teams and the significance of communication. The aim of the study has been to develop, evaluate and build an appropriate interactive map for risk assessment. The architecture in this study is based on the organisational commitment of every individual within multi-team agencies. The designing of an interactive plan requires the commitment of the team members in all the agencies. Additionally, the goal of the study is not merely producing the interactive plan but also to benefit humanity via this design and reduce the destruction and loss caused by disasters. Collaboration is the pillar of the design in this study and the success of the plan is linked to the collaboration between all the agencies. Communication is vital in this study for understanding the targets of the design and the different views when evaluating the design. The COA framework is an information architecture which enables an organisation that adopts it to work securely in an environment (Jerisho Forum, 2008). COA also enables effective collaboration which is secure. The COA framework identifies all the components that contribute to creating a secure environment for a business. COA also provides IT systems which are secure within the global network and environment (Jerisho Forum, 2008).

7.3 Conceptual Framework Design

In following the TOGAF framework and the COA framework, this research defines the collaborative risk assessment environment as a set of views namely: Team Member view, Information view, Process/Activity view, and User Interface/Workspace view as displayed in Figure 7. 1. These represent different viewpoints and are explained in detail in the following sub-sections.

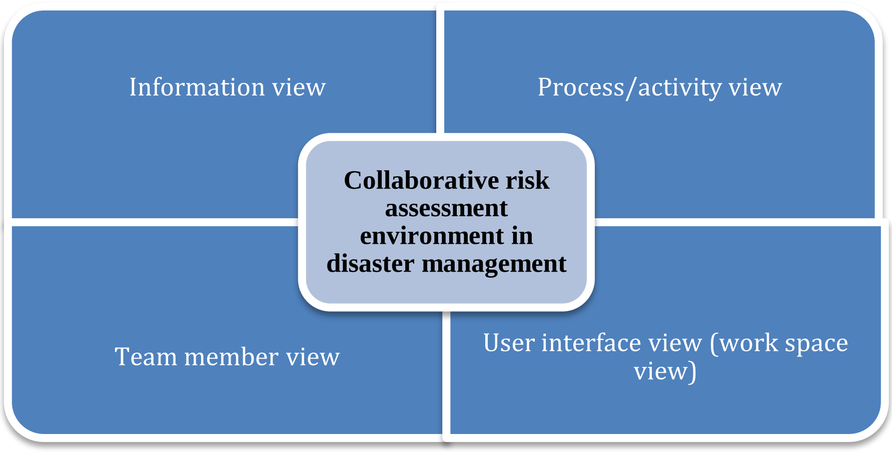


Figure 7. 1: The conceptual framework views

7.3.1 Team Member View

The collaborative platform's Team Member view defines the team members' profiles within a collaborative process. This view will be made up of representatives from the multiple agencies that are involved in the risk assessment process environment. This view would also allow all agencies to understand their role and responsibilities which are key in achieving successful risk assessment and preparedness (Table 7.1). Team members consist of representatives from the departments and agencies responsible for providing the assessments. This includes representatives of the local emergency planners and first responders such as the commanders of the police, fire and rescue and ambulance services as well as representatives from the local authority, the NHS, local transport operators and from the Environment Agency. They are engaged in this collaborative risk assessment process through a series of meetings involving assessment activities. These activities range from an initial presentation, and an analysis of threats/hazards, to a risk assessment process that collects information about threats and hazards and to assigning values to risks for the purposes of determining priorities, to collectively and individually exploring alternatives and to reaching a final agreement. The roles and responsibilities for each team member are shown in Table 7. 1 below. Ultimately, the conceptual design in this view aims to support team members to fully engage as a multi-agency team, enabling them to share their views, experiences and insights with their fellow team members in order to collectively explore and manage local risks.

Table 7. 1: A summary of the team members' profiles including roles and responsibilities

Role	**Responsibility**
Commander of Police	The police generally co-ordinate the activities of other responders, whilst ensuring that the scene is preserved and evidence safeguarded – particularly where terrorism is suspected. They arrange for any victims to be removed from the area, and, if necessary, coordinate search activities.
Commander of Fire & Rescue	The main role of fire and rescue services in an emergency is the rescue of citizens trapped by fire or wreckage. They are also responsible for extinguishing fires and taking protective measures to prevent the fire from spreading. Moreover, they assist other agencies such as the ambulance service and the police.
Commander of Ambulance Service	The ambulance service is responsible for the on-site response to short or sudden emergencies, as well as taking the victims to different hospitals, depending on priority, and the types and numbers of injured. The Ambulance Incident Commander (AIC) is responsible at the scene of an emergency.
Commander of NHS	Responsible for the managing of hospitals which the ambulance service designate as receiving casualties in the event of a major emergency, as well as a range of health professionals who would be involved in the recovery phase of an emergency which would include general practitioners, pharmacists and mental health services, amongst others.
Commander of Local Authority	Local authorities collaborate with a range of bodies to support emergency services during emergency response and recovery from disaster. Services may include shelters, medical support and long-term survivor welfare support.
Commander of Local Transport	Responsible for managing traffic, providing information to road users, improving safety and tackling road traffic, overseeing public transport. Many of the functions are relevant to emergency response.
Commander of the Environment Agency	The aim of the EA is to protect and improve the environment, dealing with many different types of incidents which affect the natural environment and human health or property. This may include issuing flood warnings, prevention/control of pollution, investigating causes of an incident.

7.3.2 Information View

The Information view of the collaborative platform allows for the presentation of multi-agency data that has been collected from diverse sources including social information such as the demographic, ethnic and social composition of the community, the geographical distribution and identification of vulnerable groups, local infrastructure such as transport, building, utilities' services (electrical substations, telecom hubs), the natural environment (such as the geographical characteristics of an area, the location and numbers of animals in an area, the plants, wildlife and sites of special environmental interest), the location and nature of hazardous sites such as chemical plants and university laboratories and the population around these sites. The collected data is brought together into a multi-dimensional data model and presented in the form of an interactive map that allows the user to view different layers of information over this map. This integrated model allows the team members to investigate various scenarios and visualise and analyse various risks' issues within a collaborative environment. It enables users to focus only on the information that is relevant to them in any given situation. The Information view defines the type of data required for conducting various risks' data assessment. This is best achieved through the combination of different kinds of data from various information sources.

The type of data identified in the Information view is based on the feedback received during the interviews with members of the multi-agency teams. The information needs that were captured from interviewees can be categorised under four main themes: Social (S), Natural (N), Critical infrastructure (CI) and Hazard sites (HS). Such information was identified as important by the interviewees, in order to enhance their decision-making processes, by giving an overview of the areas upon which they need to concentrate, including the natural geography, the areas' vulnerabilities, risk and critical infrastructure and the location of the hazards.

Table 6.1 in chapter 6 presents a detailed list of information that should be considered within the collaborative risk assessment environment. The first column presents aspects of social information, the second column presents aspects of the natural environment, the third column presents elements of critical infrastructure and the fourth column displays possible hazardous sites. This information is intended to be comprehensive, but not exhaustive; more aspects could be added.

7.3.3 Process/activity view

The risk assessment process is reflected in the design of the platform. The process view addresses how information identified in section 6.3.2 can be used to support the risk assessment process. As previously noted, the risk assessment process has six stages, which are shown in Figure 7. 2 below. The discussion as to how these activities can be supported is based on the literature review. The author's views are also brought into the discussion to offer a sensible narrative in describing a possible scenario.

Figure 7. 2: The six-step risk assessment process

The first stage involves multi-agency teams contextualizing social, natural, infrastructural and hazard site risks to fully understand the local area. This requires social information such as demographics, ethnical and social composition of the community, the geographical distribution, and identification of vulnerable groups. The system aims to provide useful social information to help multi-agency collaboration to identify local social risks. The contextualization stage also requires information on local infrastructure, such as information on an area's critical supply network and the location of, and provision of, critical services such as telecommunication hubs, healthcare facilities and financial institutions. This information supports the contextualization process by providing information that is useful for the multi-agency teams in order to identify risks to local infrastructure. In addition, natural environment information is required in the contextualization process. This includes areas that would be affected by a potential dam failure, the location and numbers of animals in an area and the impact that a disaster could have on plants, wildlife and sites of special environmental interest. Again, such information supports the contextualisation step of the risk assessment process by providing multi-agency teams with the information they need to understand local risks in the natural environment. Finally, in this stage of the process, multi-agency teams require hazard sites' information, such as the location of chemical plants and university laboratories and the population around these sites.

The second stage of the process is Hazard Review, in which past experience, historical data, research or other information is used by multi-agency teams to collectively identify significant risks. The design of the platform supports this activity by assimilating data from past events and data from research from different sources and promoting the communication of this data to all members of a multi-agency team.

The third stage is Risk Analysis, in which multi-agency teams seek to understand a local risk in terms of its likelihood, outcome and impact. The platform's design aims to support this activity by providing users with heat maps, statistics and graphs to help users estimate the likelihood of a hazard occurring and to model its impact (for example, the number of people and the amount of critical infrastructure that would be affected) and its outcome (the size, scale and location of an event).

The fourth stage is Risk Evaluation, in which multi-agency teams work together to produce a risk matrix which identifies and prioritises local risk hotspots. At this stage of the risk assessment process, the design of the platform aims to support the production of a risk matrix by providing a holistic view of the local area which can be accessed collectively.

The fifth stage is Risk Treatment, in which existing capabilities are identified and gaps in these capabilities are discussed. The design of the platform addresses this part of the process by allowing members of a multi-agency team to share the location, types and number of their available resources on an interactive map.

The final stage of the process is Monitoring and Reviewing, in which multi-agency teams seek to collaboratively update, review and maintain information regarding local risks. The design of the platform aims to address this aspect of the process by providing information that is easy to update and maintain, and which can be shared by all users.

7.3.4 Data visualisation view

This section presents a possible interface view of the interactive map. The interface provided in the platform is based on the Model-View-Controller architectural pattern (Krasner and Pope, 1988) and users are presented with a mapping space on the left of the screen and a contextual menu on the right (which are shown in Figure 7. 3 below). The mapping space is a Google Earth plugin. To navigate the map the mouse is used. Holding the left mouse button allows the user to pan, holding the middle mouse button allows users to rotate the map and holding the right button allows the user to zoom in and out of the map. Different items on the map can be selected by clicking with the mouse, with different options depending on which mouse button has been clicked.

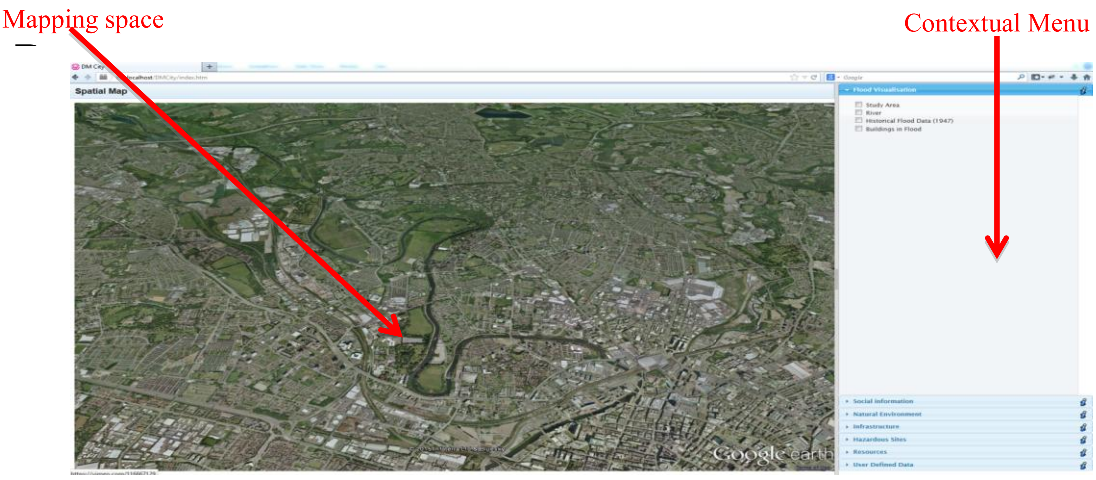


Figure 7. 3: Mapping space & contextual menu

The map can be overlaid with layers of social information, natural information, infrastructure, hazardous site, resources and flood information. The users can toggle between these layers and combine them by selecting them from the contextual menu using a mouse and keyboard, which alters the visualisation on the mapping view. The two main aspects of the interactive map, the mapping space and the contextual menu, will now be described in greater detail, starting with the mapping space.

7.3.4.1 Mapping Space (Interface)

The information is presented in the mapping space via different visualisation metaphors. These metaphors are points (icons), heat maps, highlighted transport networks, boundary maps and polygons. Each metaphor serves a different purpose.

Points are used to visualise the location of people, buildings and hazard sites. Each aspect of this information is given a different visual symbol. In some cases, these points are circles with a letter inside. For example, the point for a hospital is a circle with a letter H, while the point for a pharmacy is a circle with a letter P. In other cases, these points are pictures. Fire engines, ambulances, traffic lights, elderly people, disabled people and others are displayed with small picture symbols. The reasons for using these kinds of visual metaphor are that they are easy for the user to understand, thus reducing stress and the level of effort they need to use to understand the context of the local risk. Moreover, these points allow the user to visualise a single location or multiple locations in relation to each other. This is in contrast to the use of heatmaps which are used differently.

While points are used to visualise specific locations, heatmaps are used in the prototype interface as a visual metaphor for concentrations. For example, when visualising population density, a heatmap shows areas with high concentrations of vulnerable people with dark, warm colours like red and orange and areas with lower concentrations with colder colours like blue. A rationale for using heatmaps to visualise population density is that such maps allow decision makers to quickly identify the areas with the highest concentration of vulnerable people that may need to be evacuated. The prototype interface allows users to switch between visualisation metaphors; the user can toggle between viewing the same information with points or with a heatmap. Moreover, a heatmap can be combined with the use of points. For example, users can identify an area with a high concentration of vulnerable people with the heatmap, while also viewing the location of the nearest hospital visualised with a point. This ability to combine heatmaps with points allows decision makers to identify vulnerable people and locate the resources needed to help them. Using heatmaps to visualise population density also allows users to visualise changes in population density over time. For instance, areas with schools and workplaces will be densely populated during the day, while residential areas will be densely populated during the evening. Heatmaps allow this to be quickly understood by decision makers, in a way that points do not show.

Heatmaps are not only used to visualise population densities. They are also used in the prototype as a visual metaphor for floods, with dark, warm colours like red and orange symbolising high depths of flood and cooler colours like blue showing low depths of flood. This allows users to visualise the size of an area affected by flood. Again, this can be combined with the use of points. For example, a flooded area could be shown using a heatmap while the location of a chemical plant or electrical substation could be visualised, at the same time, with a point.

Highlighted transport networks are also included in the prototype interface. Users can switch between viewing all roads, with the names of roads displayed on-screen or only viewing major roads. Major roads are highlighted in pink on the prototype. The reason for this visual metaphor is to enable decision makers to identify important routes that need to be clear or ones that can be used to transport equipment, people or resources to, or from, an affected area. This can be combined with the use of points to represent, for example, traffic lights or hospitals to which responders need access.

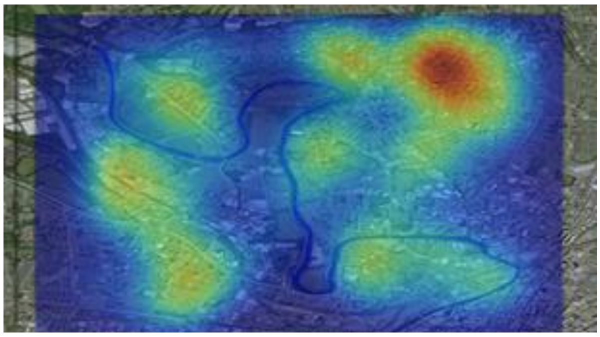
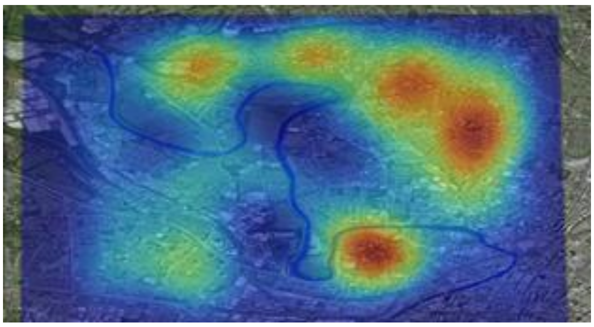
Boundary maps also use colours to represent areas, but unlike heatmaps they use one colour and do not show concentrations. On the prototype boundary maps use a colour to define a certain area, such as a national park or an animal sanctuary. Moreover, boundary maps can show the buildings and houses that would be affected by the failure of a dam at a nearby reservoir. In addition, they show the buildings supplied by an electrical substation and, therefore, which buildings would have their electricity supply cut off if the substation failed. Again, this can be combined with the use of points to visualise the locations of, for example, hospitals and schools that would be in the affected area. This enables decision makers to understand how many people, buildings, hospitals and other aspects of key infrastructure would be affected in the event of damage to a reservoir or substation.

Polygons are the visual metaphor that allows users to directly interface with the map. In the prototype, users can draw a polygon around an area of the map and give it a colour. Multiple polygons can be created with different colours. This is flexible, depending on the needs of the users. For example, polygons can simply be used to focus all team members' attention and discussion on a particular area. On the other hand, they could be used to define areas of responsibility for different agencies. For instance, a polygon given the colour red could be the responsibility of the police, a green polygon could be the area for which the fire and rescue service takes responsibility and a yellow polygon could be used to define the area for which the ambulance services has responsibility. Related to the polygons are the markers which are visualised by the symbol of a pin. As with the polygon, the pin symbol has possible numerous uses. For example, each pin could represent the location of people from different agencies in the affected area, or could be used to symbolise areas of high, medium and low risk when team members are prioritising risks.

The Table below (Table 7. 2) summarises the type of information identified and the visualisation metaphors (eg, points (icons), heatmaps, highlighted transport networks, boundary maps and polygons) that can be used to represent this information.

Table 7. 2: The type of information identified and the visualisation metaphors used

Type of interface	Type of information	Visualisation
Points	Points are circles with a picture inside, for example showing elderly people	
	Points are circles with a picture inside, for example showing those with disabilities	
	Points are circles with a letter inside. Examples are a hospital (H), pharmacy (P) and GPs (G)	

	Points are circles with a letter inside. Examples are Electrical Substations (E) Telecom substations (T) and Gas substations (G)	
Heatmaps	Population density	
	Flooded area	
	Concentrations of health care needs	

Highlighted transport networks	Transport network such as networks of roads, major roads, rail network	
Boundary maps	National parks, animal sanctuaries	
Polygon	As an example, polygons can simply be used to focus all team members' attention and discussion on a particular area	
Markers	For example, each pin could represent the location of people from different agencies in the affected area	

7.3.4.2 Contextual Menu

The contextual menu allows users to control which aspects of information they see on the mapping view by clicking different options on the menu. This is a fixed menu on the right of the screen. The rationale for using a fixed menu is that it keeps the menu in view at all times, so users do not need to remember the contents of the menu. The menu has a vertical list of main information themes (flood visualisation, social information, natural environment, infrastructure, hazardous sites, resources and user defined data). When one of the themes is selected with the mouse, all the other themes remain at the bottom of the menu. This allows users to quickly switch between them. Clicking on a theme produces a vertical list of categories of related information and clicking on these produces a vertical list of subcategories.

In the flood visualisation menu, the user is presented with the following categories: study area, river, historical flood data and buildings in flood. Each category can be turned on or off by clicking on the box next to it. Turning on the study area creates a green box on the mapping area, defining the area in which information is available. Selecting the river category highlights the river in dark blue, while turning on historical flood data produces a heatmap of previous floods. Finally, turning on the buildings affected by flood highlights buildings within the flooded areas in a colour that contrasts with the heatmap, depending on the colour of the heatmap. This stops the visualisation becoming too confusing for the user.

In the social theme menu, the user is presented with the following categories: demographics, community, mobility needs, healthcare needs and buildings hosting vulnerable people. Under the demographics' category, the user can select either population or population (night time) subcategories. These subcategories produce heatmap visualisations of the population density in either the day or night time. Under the community category, the user can select ethnic minority communities and transient population subcategories. The ethnic communities' subcategory produces coloured boundary maps, with a point showing the location of a community leader in that area. Similarly, the transient population subcategory produces coloured boundary maps showing the location of these transient communities. The mobility needs' category gives the user the option to view elderly people, people with disabilities, infants and pregnant ladies. Selecting any of these options populates the map with points (icons) or heatmaps depending on the choice of the user. The user can choose to view all people with mobility needs or select from the individual subcategories. The healthcare needs' category leads to subcategories listing serious medical needs, illness types and chronic health conditions. As in the previous category, the user has the option to view the locations of all people with healthcare needs by either points or by heatmaps, or they can select a particular subcategory in which they have an interest. The final category in the social information theme is buildings housing vulnerable people which leads the user to two subcategories: hospices and schools. Clicking on these options populates the map with points (in this case, circular symbols with the letters inside).

The natural environment theme produces a vertical list of the following categories: reservoirs, landslide areas, national parks, forests and animal sanctuaries. Clickingon the box next to any of these populates the mapping area with coloured boundary maps showing the locations of these areas.

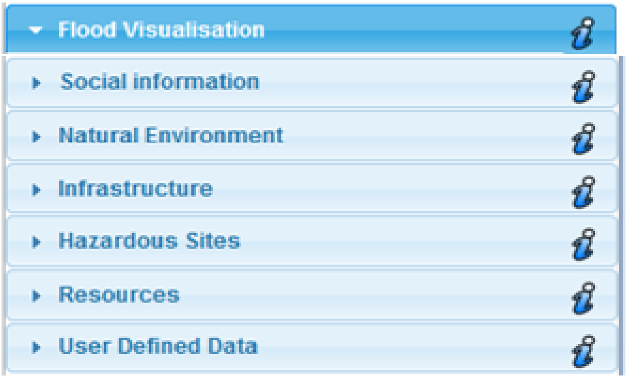
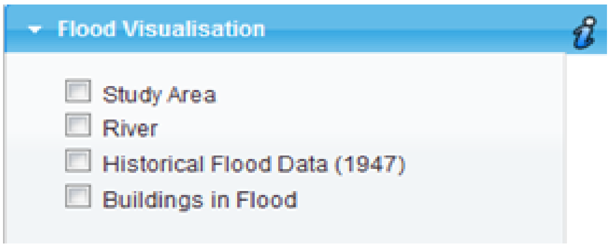
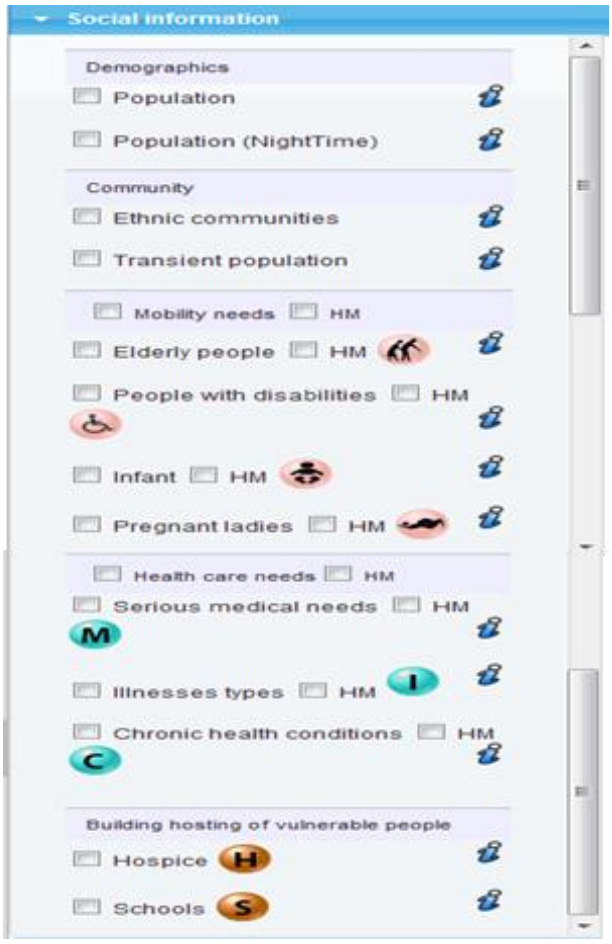
The infrastructure theme leads the user to the following categories: utility services, transport and buildings. Under the utility services category, the user is presented with a list of the following subcategories: electrical substations, telecommunication substations, gas substations and water distribution points. Next to these options are points, visualising these as circles with different letters inside (eg, E for electrical substation). Clicking on the box next to any of these subcategories populates the map with these points. Under the transport category, bridges, roads, major roads, rail networks and traffic lights are listed in a vertical list. Clicking on the traffic lights' option populates the map with points showing their location, while selecting any of the others highlights these on the map in different colours. Under the building category, the following subcategories are listed: major residential houses, financial institutions, shopping centres, universities, hospitals, GPs, pharmacists, police stations, train stations, fire and rescue stations and heritage buildings. Aside from residential buildings, which are highlighted on the map in a contrasting colour when selected, clicking on any of these options populates the map with corresponding circular icons with letters inside (eg, G for GP).

The hazardous sites' theme differs from the others by allowing the user to map a radius showing a possible affected area around a hazard site. The user can set a radius of their choice with produces a boundary map in a colour of their choice. The categories available within the hazardous sites' theme are waste disposal site, chemical factory, chemical oil rich site, university biological lab and university radiological lab. Selecting any of these options populates the map with points, again with circles and letters (F for chemical factory and so on).

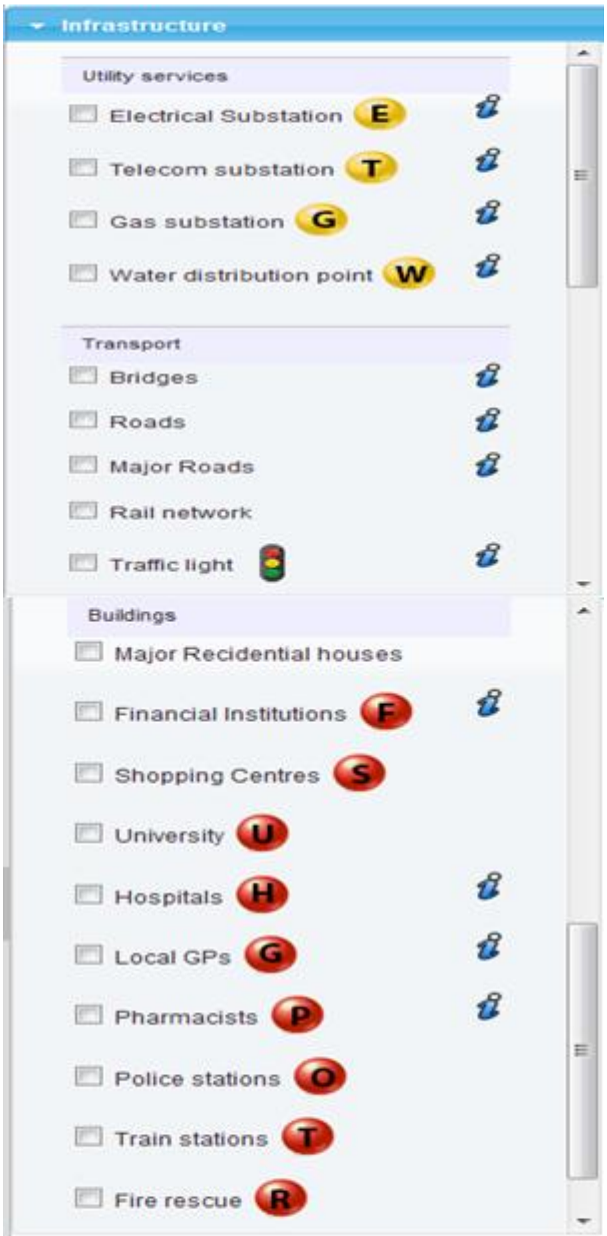
The resources' theme shows the users the location of the resources of different agencies that can be used for different incidents. The categories in this theme are fire hydrants, fire trucks and ambulances. Selecting these categories populates the map with points with picture symbols showing their location.

The final theme is user-defined data which gives the user two options. Firstly, they can draw, edit and save a polygon with a colour of their choice. Text boxes are available to label the polygon and give a description. This option is, therefore, flexible with users able to use it for various purposes, as previously noted. Users also have the option to add specific markers of various colours which can also be labelled and described. The markers are visualised by a symbol of a pin. The following Table, Table 7. 3, illustrates the design of the contextual menu for the main themes, categories and subcategories.

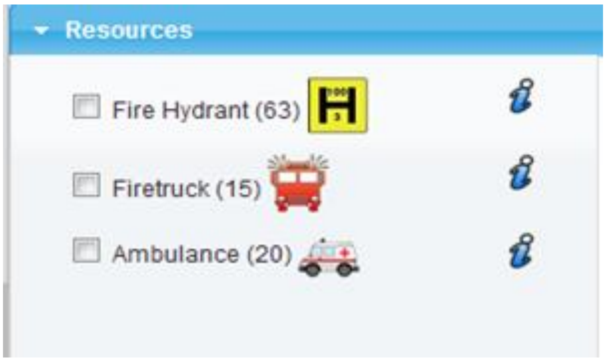
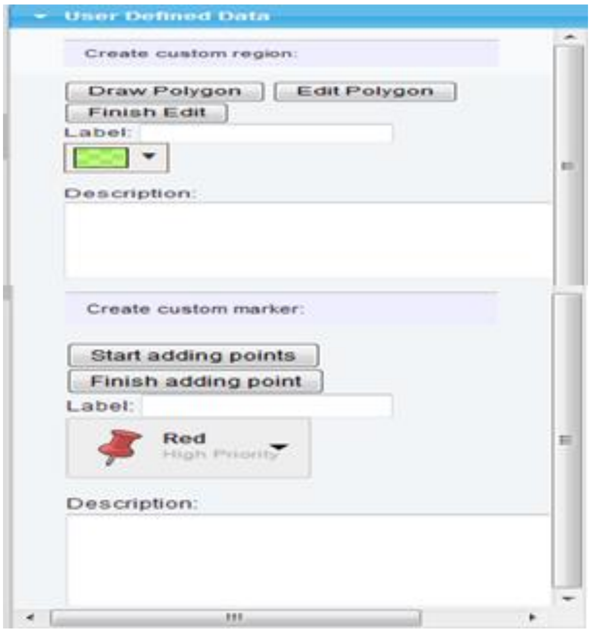
Table 7. 3: The design of the contextual menu for the main themes, categories and subcategories

<table>
<tr><th>Type of information</th><th>Contextual menu</th></tr>
<tr><td>Main menu</td><td>
</td></tr>
<tr><td>Flood visualisation</td><td>
</td></tr>
<tr><td>Social information</td><td>
</td></tr>
</table>

<table>
<tr>
<td>Natural environment</td>
<td>


</td>
</tr>
<tr>
<td>Infrastructure</td>
<td>


</td>
</tr>
</table>

Hazardous sites	
Resources	
User defined data	

The design of the platform provides a collaborative space which is open to all users and is viewed on a single, large screen. Team members interact utilising this workspace, coordinated by a presenter. The platform facilitates discussion and collaboration within a multi-agency team, allowing exploration to enhance and support multi-perspective collaboration.

7.3.5 Use of Views in Supporting Risk Assessment

The tables below show how the information presented in the Information view links to the different steps of the risk assessment process, the objectives of the multi-agency teams in each of these steps and how the visualised information can help them meet these objectives.

Table 7. 4: Social contextualisation: objectives and visualisation medium

Step 1: Social Contextualisation

Objective: to allow users to explore and understand the context of varied social intelligence (such as the demographic, ethnic and social composition of the community, the geographical distribution, identification of vulnerable groups, level of community resilience) and an interactive spatial map that could help Category 1 & 2 responders to establish a collective understanding of the local risk level.

Contextualisation		**Objectives**	**Visualisation medium**
Social information (Social vulnerability)		• To understand concentrations of vulnerable people within a city	• Present the statistics of social vulnerability as a heatmap.
Categorise	**Sub categories**		
• Demographics	I. Population densities	• To know the densities of an area's population in order to locate the resources to evacuate them.	• View population densities across affected area(s) as a heatmap.
	II. Population changes daytime/night time	• To know the location of population densities in daytime and night time within a city in order to locate the resources and and have differing plans (depending on the disaster) to evacuate them.	• View population changes in both daytime and night time across affected area(s) as a heatmap.
• Community	I. Ethnic communities who are not well integrated with society generally and have language difficulties	• To know how to reach communities' leaders by the right channels in order to inform and warn the residents	• View ethnic communities who are not well integrated with society generally

		about emergencies. • To know these leaders' location and contact details.	(and have language difficulties) across the affected area(s) as a heatmap, plus relevant communities' leaders' contact details and location points.
	II. A transient population (travellers' communities, students)	• To know how to reach these communities by the appropriate channels in order to inform and warn them about emergencies.	• View a transient population (travellers' communities, students) across the affected area(s) as heatmap, plus relevant contacts.
• Mobility needs	I. Elderly people	• To determine the type of equipment and staff needed to evacuate them in a disaster, and to see where such people might need to be evacuated. • To know their location and contact numbers. • To prioritise the evacuation of these particular people.	• View elderly people across the affected area(s) as a heatmap, plus relevant contact details (database view) and location points.
	II. People with disabilities	• To understand the support required (such as medical and transport support) and to know where such people might need to be evacuated. • To know their location and contact numbers. • To prioritise the evacuation of particular people.	• View people with disabilities across the affected area(s) as a heatmap, plus relevant contact details (database view) and location points.
	III. Families with children	• To determine the type of transport and staff needed to evacuate them in a disaster, and to know where such people might need to be evacuated.	• View families with children across the affected area(s) as a heatmap, plus relevant contact details (database view) and location

		• To know their location and contact numbers • To prioritise the evacuation of these particular people.	points.
	IV. Pregnant ladies	• To determine the type of equipment and staff needed to evacuate them in a disaster, and to know where such people might need to be evacuated. • To know their location and contact numbers • To prioritise the evacuation of these particular people.	• View pregnant ladies across the affected area(s) as a heatmap, plus relevant contact details (database view). Additional information will be found by clicking on the icon (this can be used to locate individuals with specific medical equipment needs).
• Health care needs	I. Serious medical needs (requiring specialist medical equipment for evacuation)	• To determine the type of specialist medical equipment and any special procedure required for evacuation, and to know where such people might need to be evacuated. • To know their location and contact numbers.	• View serious medical needs across the affected area(s) as a heatmap if the population is large enough. Additional information will be found by clicking on the icon (this can be used to locate individuals with specific medical equipment needs)..
	II. Specific types of illnesses (needing special procedures for evacuation)	• To determine the type of special medical equipment and any special procedure	• View specific types of illnesses across the affected area(s)

		required for evacuation, and to know where such people might need to be evacuated. • To know their location and contact numbers.	• as a heatmap if the population is large enough. Additional information can be found by clicking on the icons (e.g. to locate individuals requiring specific procedures and needs (e.g., for those with infectious diseases)
	III. Those with chronic health conditions	• To determine the type of specialist medical equipment and any special procedure required for evacuation and to know where such people might need to be evacuated. • To know their location and contact numbers.	• View those with chronic health conditions across the affected area(s) as a heatmap if the population is large enough. Additional information can be found by clicking on the icons (e.g. to locate individuals with specific procedure needs).
Building with a density of vulnerable people	I. Hospice	• To determine the best communication method to warn and instruct people to leave before they are affected by a disaster. • To determine the type of transport and staff needed to evacuate such people in a disaster, and to know where such people might need to be evacuated.	• View hospices across the affected area(s) as icons or colour coded buildings.

	• Schools	To determine the best communication method to warn and instruct those in schools to leave before they are affected. • To determine the type of transport and staff needed to evacuate those in schools in a disaster, and to know where such people might need to be evacuated.	• View schools across the affected area(s) as icons or colour coded buildings.

Table 7. 5: Natural environment contextualization: objectives and visualisation medium

<table>
<tr><td colspan="4"><u>Step 1: Natural Environment Contextualisation</u>
Objective: to allow users to explore the natural environment and understand the context of the natural resources' vulnerabilities and an interactive spatial map that could help Category 1 & 2 responders receive a better collective understanding of the likelihood of, and the impact of, an emergency in the community</td></tr>
<tr><th colspan="2">Contextualisation</th><th>Objectives</th><th>Visualisation medium</th></tr>
<tr><th colspan="2">Natural environment information</th><td rowspan="2">• To understand where there might be concentrations of natural spaces in the area concerned which might be vulnerable to disaster</td><td rowspan="2">• To present any natural vulnerabilities as a heatmap.</td></tr>
<tr><th>Categorise</th><th>Sub categories</th></tr>
<tr><td>• Reservoirs</td><td></td><td>• To assess and understand the aggregated risks that can be caused by the possibility of reservoir dams failing. This might pose a dangerous situation for people, for critical infrastructures and for the environment.</td><td>• View reservoirs across the affected area(s) - click on an icon and view a heatmap of affected area or a boundary map.</td></tr>
<tr><td>• Topography</td><td></td><td>• To use information about</td><td>• View topography across the affected</td></tr>
</table>

		the local topography to locate flood barriers. • To predict how many homes will be protected by flood barriers.	area(s) as a heatmap (for example using blue to green colours to show the areas most in danger of flooding).
• Animal sanctuaries		• To understand the requirements to feed, rehouse and move the animals.	• View animal sanctuaries across the affected area(s) as icons & as database information.
• National parks		• To understand the ecology and natural resources of a national park area (eg sites of special scientific interest).	• View national parks across the affected area(s) as icons & as database information.

Table 7. 6: Local infrastructure contextualization: objectives and visualisation medium

<u>Step 1: Local Infrastructure Contextualisation</u>

Objective: to allow users to explore and understand the context of the **local infrastructure** (transport, utilities, businesses), the critical supply network and critical services (telecommunication hubs, health, finance, etc.) on an interactive spatial map that could help Category 1 & 2 responders receive a better understanding of the likelihood and impact of an emergency in the community.

Contextualisation		**Objectives**	**Visualisation medium**
Local infrastructure information		• To understand where there are concentrations in the area(s) concerned of infrastructure that may be vulnerable in the event of a disaster	Present infrastructure vulnerability across the affected area(s) as a heatmap & by icons showing the priorities within this sector
Categories	**Sub categories**		
• Electrical Substations		• To understand the numbers of people and buildings that would be affected by the loss of a substation. • To identify key infrastructure that would	• View electrical substations across the affected area(s) as icons. Click on the icons and view the affected area(s)

		be affected by the loss of a substation. • To use this information to create priorities in planning, especially for evacuations.	as a coloured area.
• Telecom substations		• To understand the number of key buildings and services that would be affected by the loss of a telecommunication substation. • To determine alternative communication methods for ensuring contact if there is a loss of a telecommunication substation and also determine how to provide the backup for this substation.	• View telecom substations across the affected area(s) as icons. Click on the icons and view a boundary map of the affected area(s).
• Water distribution point		• To identify how many people, houses, buildings, hospitals and other key infrastructure would be affected by the loss of such a point. • To use this information to create priorities in planning. • Take protective measures.	• View water distribution points across the affected area(s) as icons. Click on an icon and view a boundary map of the affected area(s).
• Gas substations		• To understand how many people, houses, buildings, hospitals and other key infrastructure would be affected by the loss of such a substation. • To understand the outcome of any explosion or damage in a gas substation and undertake preventive action.	• View gas substations across the affected area(s) as icons. Click on the icons and view a boundary map of the affected area(s).
• Health facilities; Local GPs, Walk-in clinics, Doctors, Nursing homes, Hospitals &		• To identify the location of health facilities within high-risk areas of flooding. • To identify the health	• View health facilities across the affected area(s) as icons. Click on an icon and view a

Pharmacists		facilities that could take casualties. • To use this information to create priorities in planning and evacuation.	boundary map of the affected area(s).
• Heritage buildings & sites		• To identify intrinsically valuable heritage buildings and sites, and asses which are more vulnerable to risk. • To use this to create priorities in planning and protection.	• View heritage buildings & sites across the affected area(s) as icons. Click on an icon for cost and heritage implications.
• Major financial institutions		• To identify which are vulnerable financial institutions and how to reach them in short time in order to protect them.	• View financial institutions across the affected area(s) as icons. Click on the icons and view cost and service implications.
• Road networks		• To identify and prioritise roads which lead to critical facilities such as schools, hospitals and police stations. • To understand the economic impact of flooding on sections of the road network. • To use information about key roads to plan alternative ways to reach people who need to be evacuated.	• View road networks across the affected area(s) as map overlays showing important routes that need to be kept clear and functioning.

Table 7. 7: Hazards sites' contextualization: objectives and visualisation medium

<u>Step 1: Hazards Sites' Contextualisation</u> Objective: to allow users to explore and understand the context of potential hazardous sites and their relationships to communities or sensitive environmental sites on an interactive spatial map that could help multi-agencies to understand the likelihood of, and the impact of, hazardous events in the local area.		
Contextualisation	**Objectives**	**Visualisation medium**
Hazards' sites information **Categorise**	• To understand concentrated hazards' sites in a city and the aggregated risks that such a hazard might pose for people, critical infrastructure and the environment.	• Present hazards' sites across the affected area(s) as icons showing priority of

		problem what priority has been given to them?
• Chemical sites (Chemical storage sites, Chemical factories, Oil rich sites)	• How to reach people living within the neighbourhood of a chemical site to communicate with them regularly and teach them what to do in emergencies. • To assess and understand the aggregated risks that such a hazard might pose for the environment. • To understand the types of material being used at the site to allow best planning for the emergency services.	• View the chemical sites across the affected area(s) as icons. Click on the icons to show the surrounding population density (on a boundary map) and the potential risks (database information).
• University labs (Biological, Biometric & Radiological risks)	• To identify the types of strains of bacteria and viruses and radiological risks within these labs and know what arrangements the staff have in place for evacuation. • To also assess the danger the above risks might pose to the animal, plant or human population. • To understand the types of material being used at the sites to allow best planning for emergency services.	• View university labs across the affected area(s) as icons. Click on the icons to show surrounding population density (a boundary map) and potential risks (database information).

Table 7. 8: Combination of contextualization (social, environmental, infrastructure, hazardous sites): objectives and visualisation medium

Step 1: Combination of Contextualization (social, environmental, infrastructure, hazardous sites)

Objective: to allow users to explore and understand the context of a combination of risks (social, environmental, infrastructure, hazardous sites) in an interactive map which could help Category 1 and 2 responders build up an integrated view of the local risk context.

Combination of (social, environmental, infrastructure, hazardous sites) information	Objectives	Visualisation medium
• Flood map with properties that are at risk overlaid with vulnerable groups and critical infrastructure.	• To help practitioners to have a broader view and aid decision- making both prior to an incident for planning purposes and during an incident. To guide the allocation of resources to mitigate that risk.	• Present flood map with properties that are at risk overlaid with vulnerable groups and critical infrastructure across affected area. Ability to turn on and off predefined layers of information to make

		decision-making easier.
• Combination of river flooding and failure of reservoir dams and electricity substations.	• To understand the impact on the human population, the natural environment and other infrastructure. To help professionals to prioritise the risks and to guide the allocation of resources.	• View combination of river flooding and failure of reservoir dams and electricity substations and reservoirs across affected area. Ability to turn on and off predefined layers of information to make decision-making easier.
• Combination of flood outcome and demographics	• To understand population density within the area, and thus how this will affect evacuation plans and, in turn, how this will affect what resources that are required to mitigate risks. • To understand the concentration of population in areas of the city. To guide evacuation plans and the allocation of resources.	• View combination of flood outcome and demographics across the affected area. Ability to turn on and off predefined layers of information to make decision-making easier.
• Combination of flood outcome with infrastructure	• To understand what could be damaged or destroyed by flooding and the cascading effects that could follow.	• View combination of flood outcome and infrastructure across the affected area. Ability to turn on and off predefined layers of information to make decision-making easier.
• Combination of flood outcome and population densities overlaid on a layer showing vulnerable people	• To guide evacuation planning so that vulnerable people can be evacuated or given support if they are not able to be evacuated. To understand the range of evacuation support required (such as medical support) and to know where evacuated people would need to be sheltered.	• View combination of flood outcome and population densities overlaid on a layer showing vulnerable people across the affected area. Ability to turn on and off predefined layers of information to make decision-making easier.

Table 7. 9: Hazard review: objectives and visualisation medium

<u>Step 2: Hazard Review</u>

Hazards that present significant risks are identified on the basis of experience, research or other information. These hazards are shared and discussed at LRF meetings with a view to agreeing a list of hazards to be assessed. An interactive map could help Category 1 & 2 responders capture experience, intelligence and research data and communicate them to others during hazard review meetings.

Hazards' Review **Categorise**	**Objectives**	**Visualisation medium**
• Previous experiences/ historical data	• To assess hazard sites which could pose a risk by showing them on a map and everyone sitting around a table studying the data, or exploring a site on the map from different points of view. Also assisting in giving a clear picture about priorities and hazards' identification. • To understand the impact of similar emergencies in order to estimate the effect on human population (such as casualty numbers and incident size etc), the natural environment and other key infrastructure. Also in order to learn from the actions and experiences of others.	• The map will allow users to visualise past data, such as the effect of river heights or rainfall (flooding) on a populated area and its infrastructure. This could be achieved through graphs or possibly through visualising the movement of the water level (up and down)in a river. The map could be controlled using a time line allowing users to scroll through time and visualise the differing water levels. This same approach could be applied to other data sets such as fire, etc.
• Research data such as university studies; social information, environmental information and hazards' information such as wildfire, flooding and volcanic ash, etc.	• State-of-the-art studies and information involved in on such areas as: I. Climate change impact. II. Heat island effect. III. An aging population. IV. Social aspects (resilience, feedback).	• Simulation. Data visualisation through graphs and heatmaps. In addition. hazards and risks could be visualised on GIS data geospatially. Providing users with location of potential problems overlaid onto mapping information allowing for incident planning and scenario training.

Table 7. 10: Risk analysis: objectives and visualisation medium

<table>
<tr><td colspan="3"><u>Step 3: Risk Analysis</u>
The purpose of Risk Analysis is to allow users to explore and understand the likelihood of, and the outcome and impact of, a hazard. Also the purpose of this section is to explore how the collaboration of both Category 1 & 2 responders could be enhanced in elaborating this assessment.</td></tr>
<tr><td>Risk Analysis
Categorise</td><td>Objectives</td><td>Visualisation medium</td></tr>
<tr><td>• Analyse social information, infrastructure, environmental information, hazardous sites' information and the outcome of hazards</td><td>• To understand which areas are at high and medium risk of flooding and help planners to analyse threats to population, key infrastructures such as electrical substations, telecommunication substations, the road network and health facilities.
• To understand the economic impact, e.g how many houses and commercial buildings would be affected, the cost of restoring each house and buildings after the flood and the modelling of the impact that, for example, road closures would have on businesses in a given area.
• To understand how the public's access to the Internet can influence how well agencies are able to inform and warn the residents about emergencies</td><td>• Simulation. 3d visualization of an appropriate area with block massing to represent buildings. Overlaid on to this base model will be labels identifying important sites (hospitals, hazards etc.). The model would also have the ability to overlay heatmaps or to visualize graphs to facilitate a better understanding of disaster management.</td></tr>
<tr><td>• Cascading effects</td><td>• To understand the cascading effects of floods on the human population, the natural environment and other key infrastructures (for example, the loss of a substation can cause the electricity supply to thousands of households to be cut off; also the loss of electricity can affect businesses and, therefore, the local economy).</td><td>• Modelling cascading effects. In the example of the flooding of a substation the loss of power would affect an area around the substation. This could be visualised as a graphical overlay on a map. Then any critical services that are supplied in this area could be identified (eg, a hospital). This identified service may supply a larger area. This could also be visualized. This ripple effect could continue to be modelled as it gradually fades. Colour mapping would be a good way to achieve this.</td></tr>
</table>

Table 7. 11: Risk evaluation: objectives and visualisation medium

Step 4: Risk Evaluation Allowing users to product a risk matrix which is an essential part of the risk assessment process. The notion of risk is divided into four risk ratings (very high, high, medium and low). These are used to indicate the risk level of a given hazard		
Risk Evaluation Categorise	**Objectives**	**Visualisation medium**
• A risk matrix	• Allow the practitioners to move between different views to evaluate and weigh the risks according to their potential environmental, economic and social impacts. This would help planners and policy makers in identifying and prioritising risk hotspots in the area.	• Providing the ability to draw polygons indicating high risk, medium risk and low risk with traffic light colours.

Table 7. 12: Risk treatment: objectives and visualisation medium

Step 5: Risk Treatment Allowing users to visualize the capabilities required and the capabilities in place on an interactive map would help agencies to collectively understand the capability gaps and address the additional treatments required to close the capability gaps and manage the risks more effectively.		
Risk Treatment Categorise	**Objectives**	**Visualisation medium**
• Multi-agency capabilities	• Allow planners to share information relating to responders' capabilities, so that multi-agency teams have a clearer understanding of their collective capability. Also to identify the location of responders' resources which could be used to deal with, and mitigate, the impact of flooding (for example, the Environment Agency and a fire fighter can identify where the risk is then decide where they will put their pumps). • Allowing planners to use special tools such as animation, highlighting and markers to mark and point on an interactive map. The user can also use the distance-measure tool to estimate the distance between a building and the nearest shelter in order to evacuate people in case the building is at high risk.	• Visualisation of the geospatial location of organizational resources allowing for a discussion of the best combined response. • Ability to drop down markers and notes to create or highlight points of interest.

Table 7. 13: Monitoring and reviewing: objectives and visualisation medium

<table>
<tr><td colspan="3"><u>Step 6: Monitoring and Reviewing</u>
The availability of intelligence collected from Step 1 to Step 5 within an interactive map in an integrated form could help Category 1 & 2 responders to continuously improve risks' management strategy and build resilient communities</td></tr>
<tr><td>Monitoring and Reviewing</td><td rowspan="2">Objectives</td><td rowspan="2">Visualisation medium</td></tr>
<tr><td>Categorise</td></tr>
<tr><td>• Need to bring together comprehensive data on a single platform and ensure that the data is constantly updated.</td><td>• The need for a comprehensive data system to be properly updated, reviewed and maintained. This data can then be monitored and reviewed on an ongoing basis which would help with the ongoing monitoring of risks. Having a comprehensive collection of data brought into one place would help planners to have access to visual information at any time, whenever it was needed.</td><td>• For the system to run effectively it would need annual updating, the keeping of accurate data and it needs to allow for any infrastructure changes to be visualized. However, in some cases important changes would have to be implemented quickly. (such as new substations, hospitals, etc).</td></tr>
</table>

7.4 Implementation of the Risk Assessment Environment

Since the author is not a technical person, a senior software specialist in the Think Lab, University of Salford, conducted the implementation of the risk assessment environment. The author worked closely with the technical specialist to ensure the risk assessment environment was implemented with the appropriate functionality and user interface as described in the previous section. The next section presents the design of the platform in-depth.

7.4.1 Design of the Platform

The interactive map prototype presents the user with a map of an area. Using an interface, a user can place different layers of information over this map. The layers of information are: social information, natural information, infrastructure, hazardous sites, resources and flood information. The system is designed using the Model-View-Controller architectural pattern (Krasner and Pope, 1988). Corresponding to this model, the system's three key elements are (as shown in Figure 7. 4):

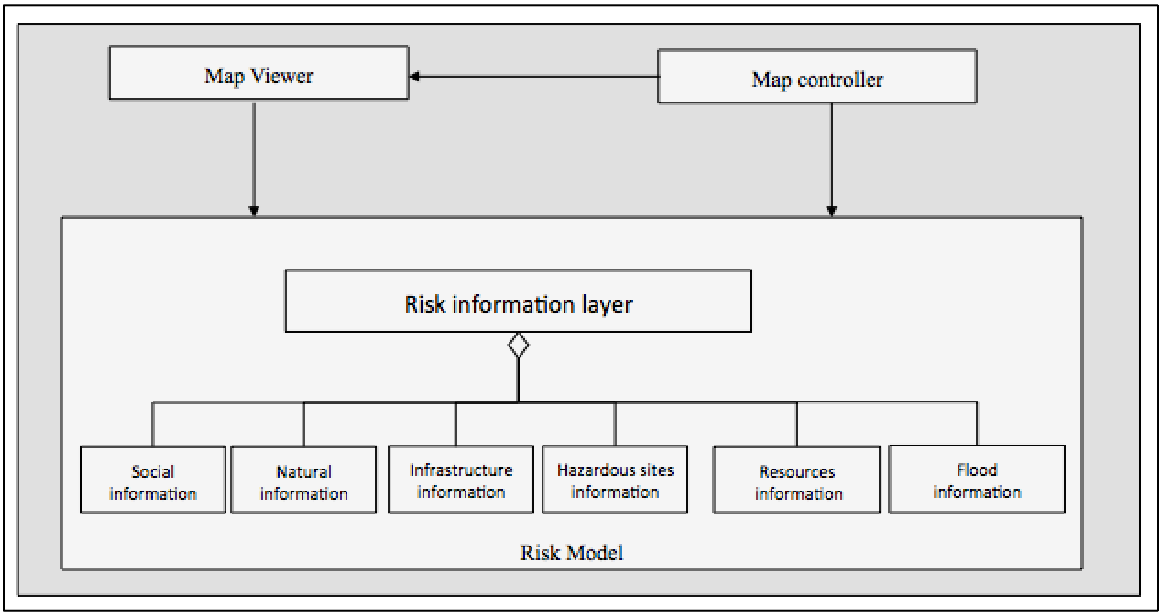


Figure 7. 4: System design

Risk Model: this provides the core of the risk information on the system. This illustrates the types of information and the structure required for the platform. The Risk Model is constructed from the underlying database system running on the server side.

Map Viewer: this is an interactive map which can present the risk models via various visual layers on top of it to the users. The map uses Google Earth as a plugin in a web browser that can run on the user's computer.

Map Controller: this provides the interface allowing users to configure the Risk Model for visualising results on the Map View and also to navigate within the Map View. The layers of information that were depicted are explained below.

Within the risk model, the Risk information layer contains information such as social information, natural information, infrastructure information, hazardous sites' information, resources and flood information. Map viewer retrieves and displays the data from the risk model. The Map Controller is for controlling and navigating the Map Viewer. It can also update the data in the risk model.

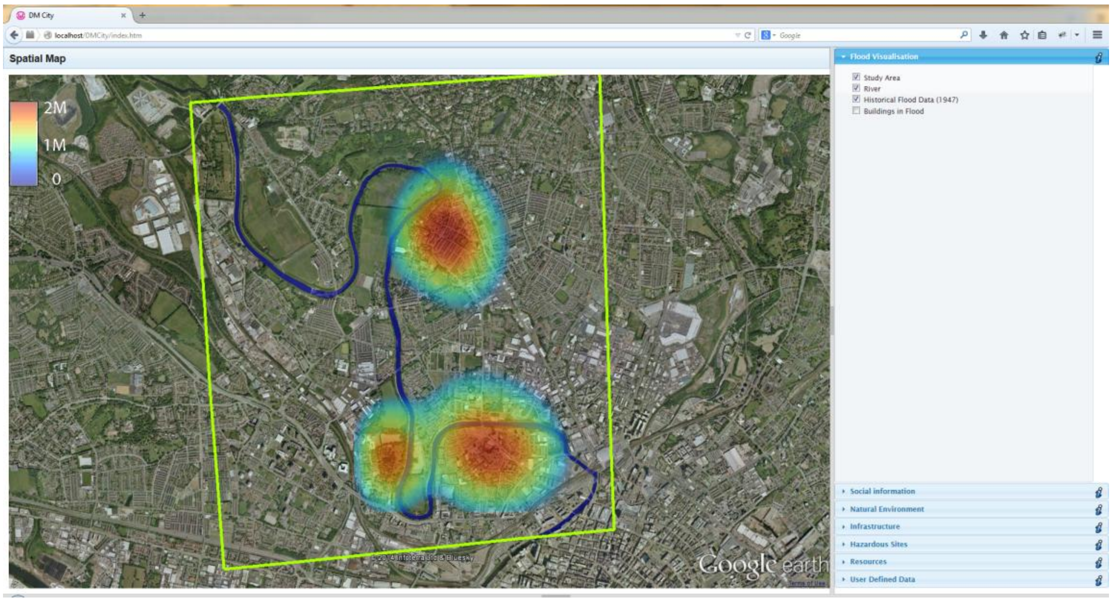


Figure 7. 5: Flood area layer

Figure 7. 5 shows the flood area layer used in this research to demonstrate the functionality of the overall interactive map and for the validation of the interactive map. This layer shows a flood scenario based on historical data from a flood that occurred in 1947 which affected the local area. A heatmap method is used to present flooded area. Furthermore, flooding areas can be coloured based on their water depths. It can range from light blue, blue to green and from orange to red and dark red. The red or dark red colour would indicate a high value of water depth or a dangerous level and the light blue or blue colour would indicate a low value of water depth.

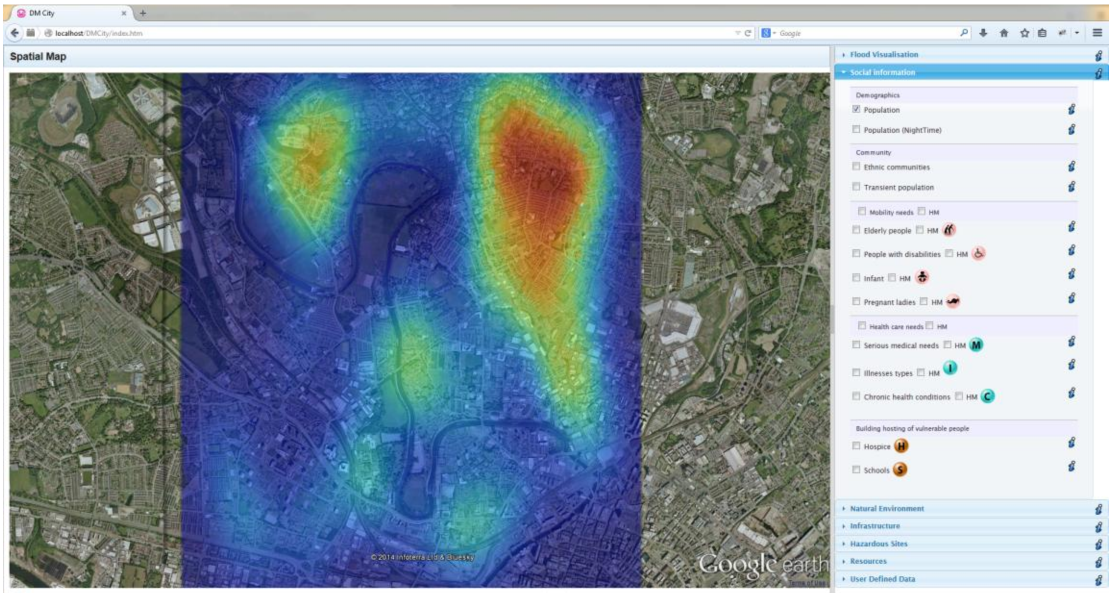


Figure 7. 6: Social information: demographics layer

Figure 7. 6 shows the study area with a layer of social information, from the demographics category. In this layer, users can view the population demographics of day and night times. The heatmap method is used to show this information. Dark red indicates high population density, while blue indicates a lower population density.

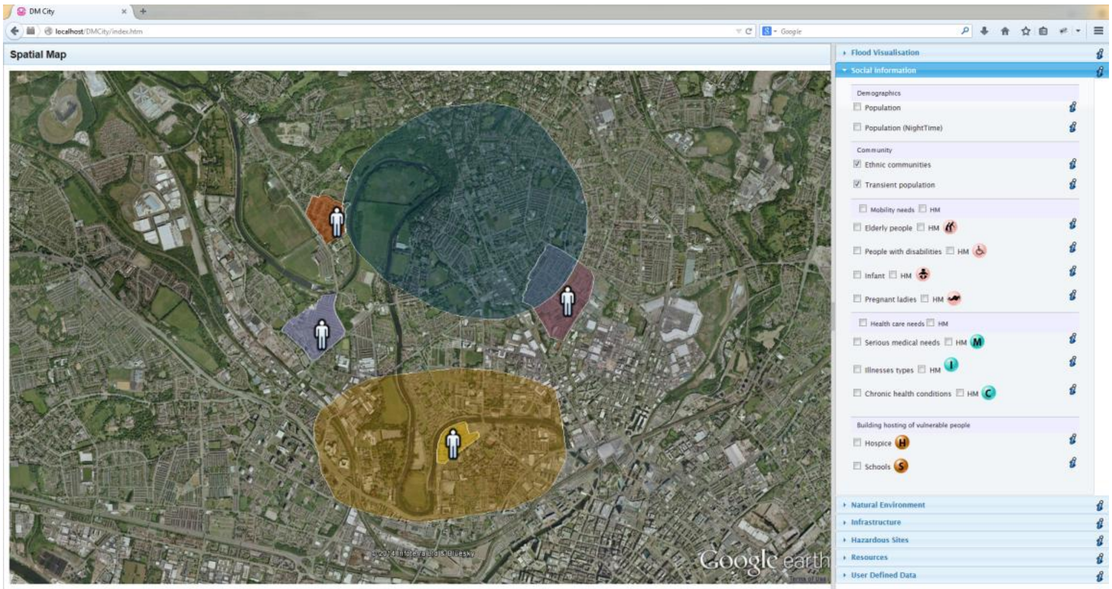


Figure 7. 7: Social information: community layer

Figure 7. 7 shows the study area overlaid with the second category of social information. This category is community, which is made up of ethnic communities and transient populations. In this layer, users see the location of different communities, with the leaders of these communities identified.

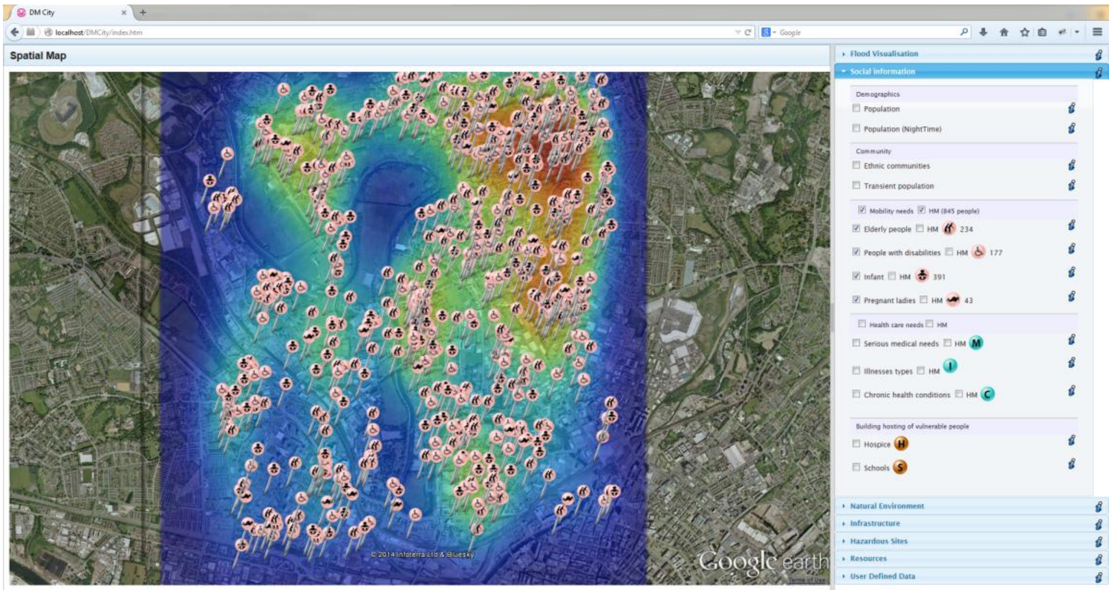


Figure 7. 8: Social information: mobility needs' layer

Figure 7. 8 shows the study area overlaid with information from the third category of social information - mobility needs. This displays a heatmap showing the population density of people with mobility needs and also icons representing the location of these people. A different icon represents elderly people, pregnant women, disabled people and infants. Users can switch between these icons to display different layers and can also view the density of a particular group population using the heatmap.

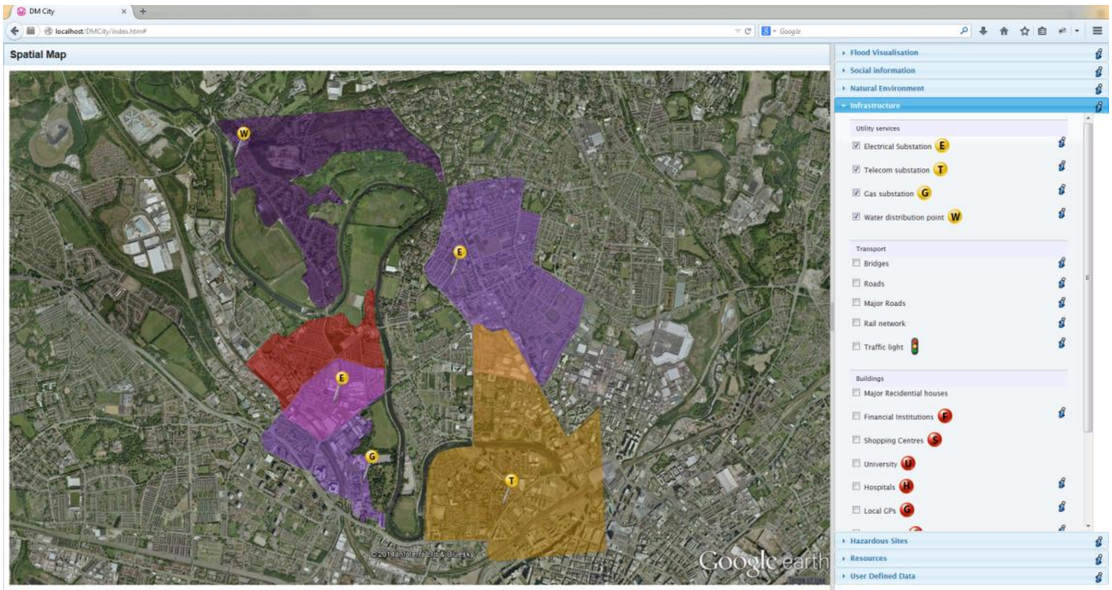


Figure 7. 9: Infrastructure information: utility services' layer

Figure 7. 9 shows the study area combined with the layer showing infrastructure information, from the category of utility services. This layer has icons showing the location of electrical, gas and telecommunication substations and water distribution points, as well as coloured areas displaying the areas that are serviced by these utility providers. Again, in this layer users can toggle between this information, showing this information in different combinations or all at once.

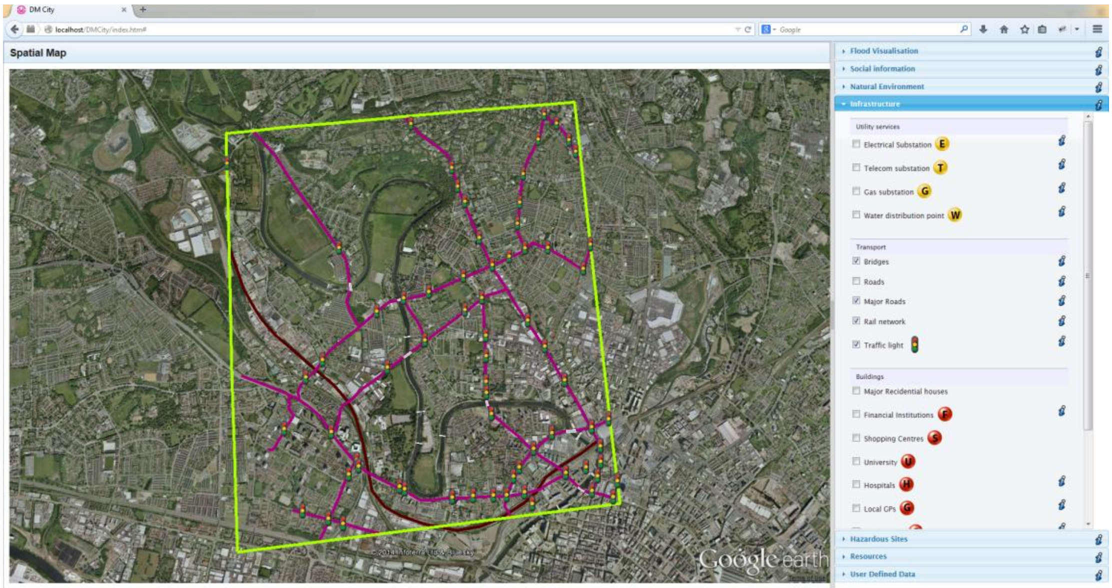


Figure 7. 10: Infrastructure information: transport layer

Figure 7. 10 shows the study area combined with another layer of infrastructure information, from the category of transport relating to major road and rail infrastructure. Icons show the location of traffic lights, while major roads and railway lines are highlighted in colour. Again, in this layer users can switch between this information, showing this information in different combinations or all at once.

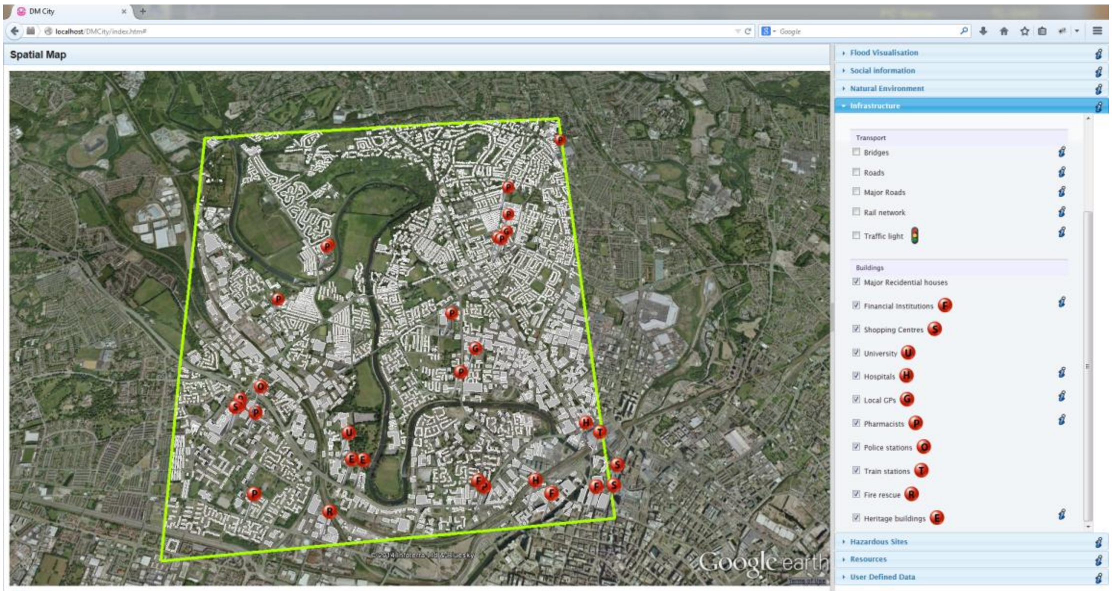


Figure 7. 11: Infrastructure information: building layer

Figure 7. 11 shows the study area combined with another layer of infrastructure information, relating to the location of different types of building in the study area. Icons show the location of residential houses, financial institutions, shopping centres,

universities, hospitals, local GPs, pharmacists, police stations, train stations, fire and rescue stations and heritage buildings. These symbols are viewed on a 3D map and users can switch between the different buildings they want to view or view all of them simultaneously.

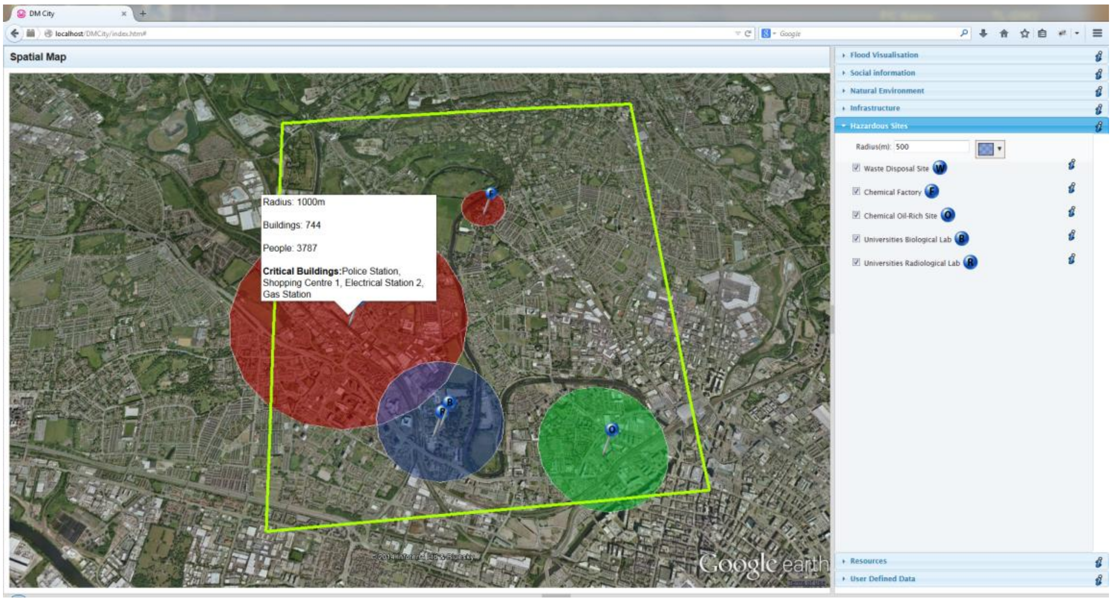


Figure 7. 12: Hazardous sites' layer

Figure 7. 12 shows the study area combined with a layer showing hazardous sites' information. Icons show the location of waste disposal sites, chemical factories, chemical oil-rich sites, university biological laboratories and university radiology laboratories. The zones that have a high risk of being affected by an incident at these sites is also mapped with colour and users can alter the radius of the affected zones. Furthermore, the user can also view key information about these affected zones including the number of houses, people and critical buildings within them. Again, in this layer users can choose to view different hazardous sites in isolation or in combination.

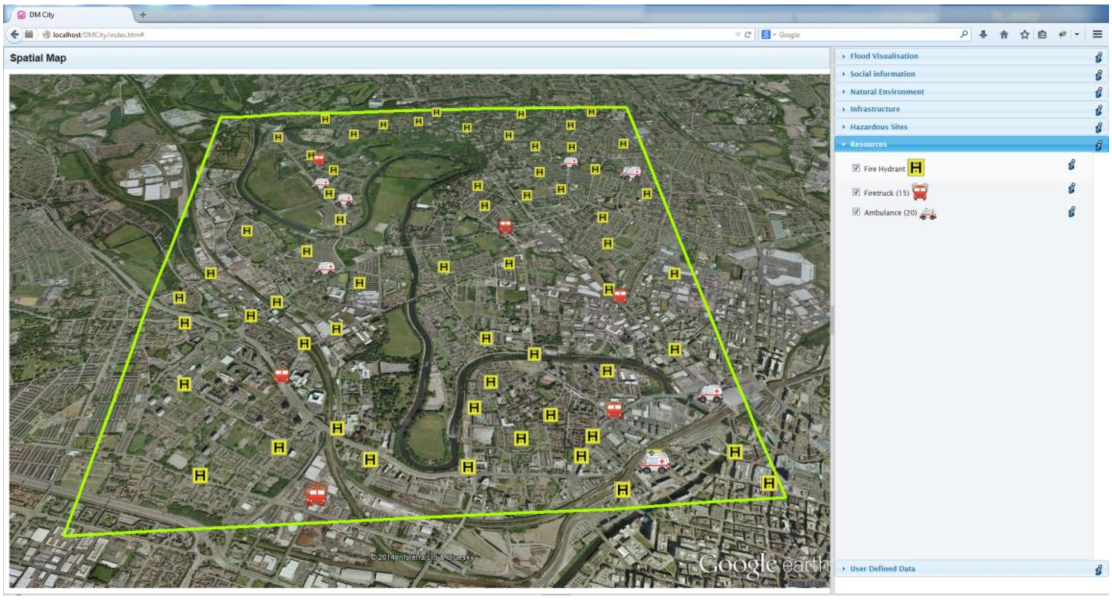


Figure 7. 13: Resources' location layer

Figure 7. 13 shows the study area combined with a layer of information showing the capabilities and resources of multi-agency teams. Symbols represent the location of fire hydrants, fire engines and ambulances. As with the other layers, users can toggle between this information, displaying part or all of it on the map.

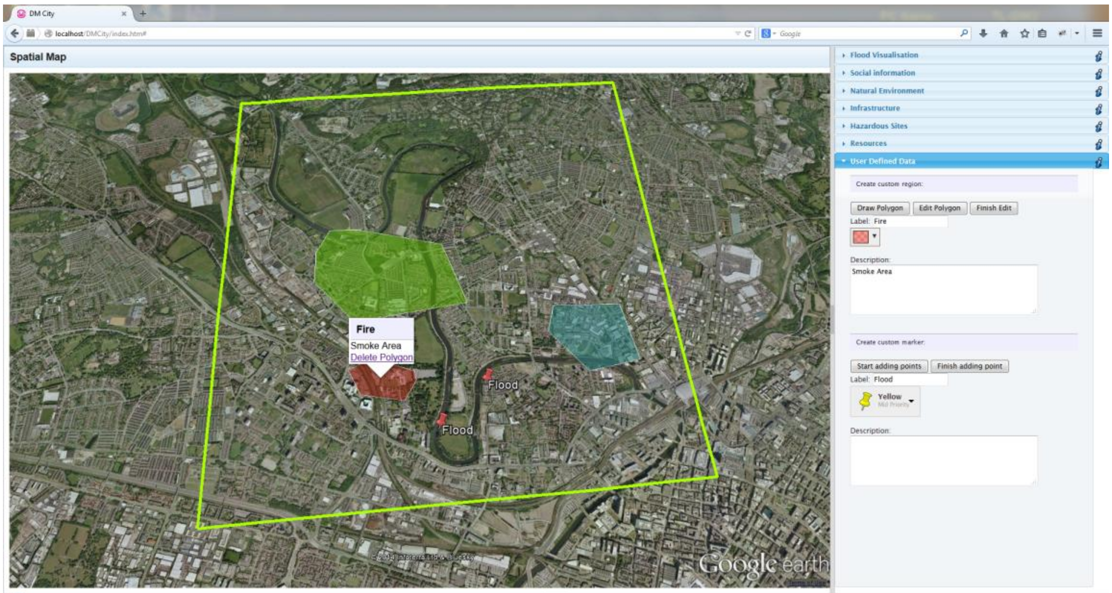


Figure 7. 14: User defined data layer

The layer shown in Figure 7. 14 allows the user to mark an area of their choice and to write comments and make notes relating to the area. All users from the multi-agency teams can view this information.

In summary, an important part of this system is the ability of users to overlay and combine any of these layers to collectively understand the local risks and to see the connections between each layer of information. The system brings together, and visually represents, a range of information that users in multi-agency teams can customize to suit their situation, promoting visual thinking and enhancing strategic planning.

7.5 Summary

The collaborative design framework presented in this chapter is based on the requirements that emerged from the literature review and from interviews with the stakeholders. The system's conceptual design consists of four views: Information view, Process/Activity view, User Interface view and Team Member view. This design aims to provide multi-agency team members with a variety of information from different sources and disciplines (Information view) that is directly linked to the stages of the risk assessment process (Process view), bringing this information together in an interface which incorporates a mapping view and a contextual menu (User Interface view). The overall goal of this conceptual design is to provide a collaborative space where a multi-agency team can collaborate, visualise, discuss and understand all aspects of the local area's risks.

Following the well-established and successful COA and TOGAF frameworks has enabled the conceptual design to build on previous foundations for an effective and flexible collaborative environment that can support and enhance multi-agency collaboration in the risk assessment process. The next chapter presents the evaluation methodology of an interactive map prototype in order to test its ability in supporting collaboration and in enhancing the multi-agency teams' risk assessment process.

Chapter 8 – System Evaluation Methodology

8.1 Introduction

This chapter presents the evaluation of the interactive map prototype that has been developed based on those characteristics that are captured through interviews' analysis. This helps to test its ability in supporting collaboration and in enhancing multi-agency teams' risk assessment process. The risk assessment process has six stages and the interactive map is intended to improve collaboration at each step. The first stage is Contextualization, in which multi-agency teams seek to understand the social, natural, infrastructure and hazard site risks in a local area. The second stage is the Hazard Review, in which multi-agency teams seek to collaboratively identify significant risks on the basis of past experience, historical data, research or other information. The third stage is Risk Analysis, in which multi-agency teams seek to collaboratively identify the likelihood, outcome and impact of, local risks. The fourth stage is Risk Evaluation, in which multi-agency teams seek to collaboratively identify and prioritise local risk hotspots through the production of a risk matrix. The fifth stage is Risk Treatment, in which multi-agency teams seek to collaboratively identify existing capabilities to treat risks, to identify gaps in the capabilities available and to fill these gaps. Finally, the sixth stage is Monitoring and Reviewing, in which multi-agency teams seek to collaboratively update, review and maintain information regarding local risks. The collaboration within multi-agency teams is based on understanding local risk information, discussing it and then making a collective decision based on this information. This evaluation investigates the look, feel and functionality of the system, the information that the system makes available and, finally, it asks how well the system enhances collaboration throughout the risk assessment process.

8.2 Evaluation Methodology

The following section describes the methodology used to evaluate the interactive map prototype and outlines all the considerations and procedures involved in this evaluation. These considerations are: what to assess, the assessment criteria, assessment setting and assessment techniques and methods. What to assess relates to the risk assessment process and interactive and collaborative multi-agency decision-making. The assessment goals relate to the 'perceived effectiveness' of the potential of the interactive map prototype in supporting risk assessment process activities and for strengthening the collaboration between multi-agency. The assessment setting describes the location of the assessment within the University of Salford Think Lab and includes the 23 subjects from the Greater Manchester LRF Development Group. Furthermore, it also describes the experimental prototype that was used and the flood scenario that the experiment was based upon. Finally, the assessment techniques will explain the workgroup that was conducted and the questionnaire which was designed to capture subjects' views using open, closed and rating scales' questions. This evaluation methodology is illustrated in Figure 8. 1.

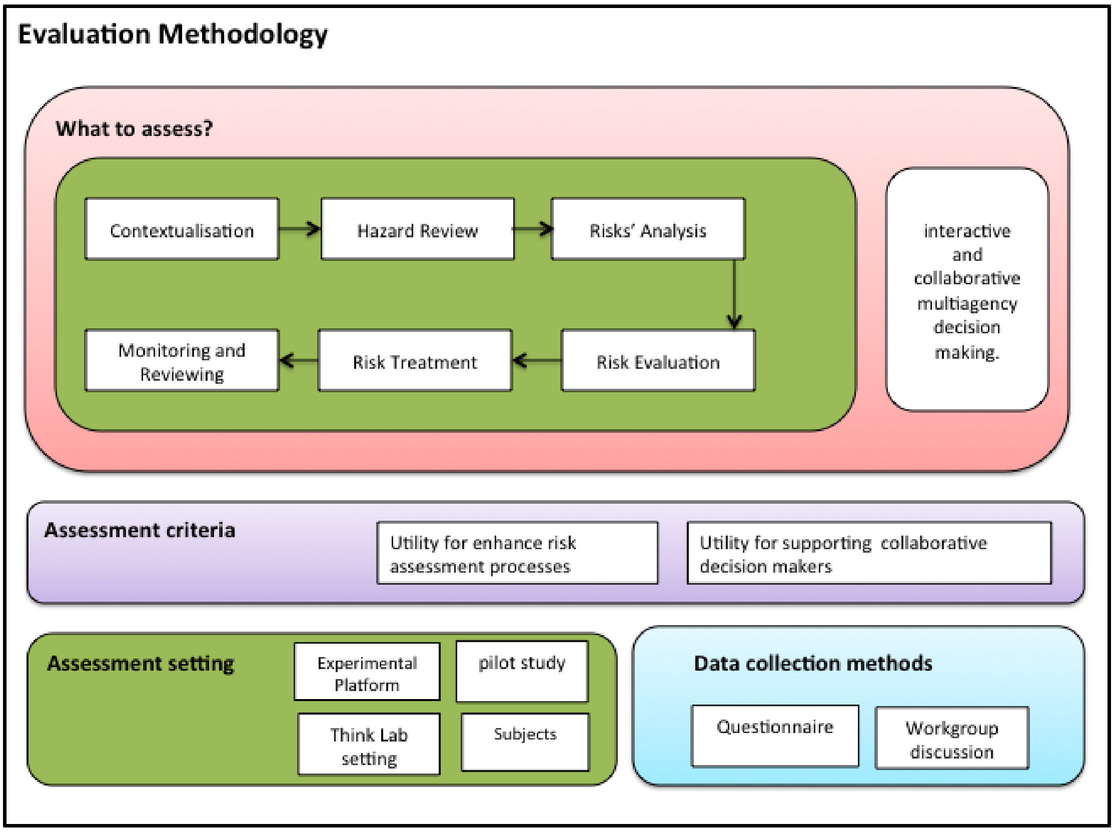


Figure 8. 1: Overview of the evaluation methodology

8.2.1 What to Assess

The purpose of the evaluation was to test if the prototype of the interactive map could enhance team collaboration in each step of the risk assessment process. This involved a number of related aspects. These included how well the interactive map presented information in a visual form that could be understood by all the members of a multi-agency team, the map's ability to combine information layers, and the ability of the users to interact with the map and navigate the information space in order to enhance their understanding of local risks. This has two aspects, which are explained below.

First Aspect: perceived effectiveness of the potential of the interactive map in supporting risk assessment processes.

This involves assessing the map's 'perceived effectiveness' in the activities carried out by multi-agency teams at each step of the risk assessment process.

Step 1: Contextualization

In this section the notion of "collective understanding" has been used. A group collective understanding is when the group members performing as a "we" and not an "it" (Holder & Reidy, 2013) hold something 'jointly' as a 'plural subject'. Collective understanding, simply, is about shared points of view about something (Skarzynski & Gibson, 2008). It can be measured using the '***perceived effectiveness'*** of the potential of the interactive map in supporting risk assessment processes.

Question 1: Does the social information on the interactive map help multi-agency teams to collectively understand local social risks?

This question measures the 'perceived effectiveness' of the interactive map in helping multi-agency teams in their collective understanding of local social risks. These risks are related to information such as the demographic, ethnic and social composition of the community, geographical distribution, and the identification of vulnerable groups.

Question 2: Does the local infrastructure information on the interactive map help multi-agency teams to collectively understand local infrastructure risks?

This question measures the effectiveness of the interactive map in helping multi-agency teams obtain a collective understanding of local infrastructure risks. This information concerns an area's critical supply network and the location of, and provision of, critical services, like telecommunication hubs, healthcare facilities and financial institutions.

Question 3: Does the interactive map help multi-agency teams to establish a collective understanding of important natural resources within that area that is being looked at?

This question measures the effectiveness of the interactive map in helping multi-agency teams to a collective understanding of the important natural resources of the area that has been looked at. This relates to how the interactive map provides information on the areas that could be affected, for instance, by a potential dam failure, the location and numbers of animals in an area and the impact that a disaster could have on plants, wildlife and sites of special environmental interest.

Question 4: Does the hazardous sites' information on the interactive map help multi-agency teams to collectively understand the local risks imposed by their hazardous sites?

This question measures the effectiveness of the interactive map in helping multi-agency teams to a collective understanding of the local risks imposed by hazardous sites. This relates to how the interactive map provides visualised information about the location and nature of hazardous sites (such as chemical plants and university laboratories) and the population around these sites. The evaluation focused on how this information was useful to multi-agency teams in identifying local risks.

Step 2: Hazard review

Question 5: Does the interactive map help multi-agency teams capture experience, intelligence and research data and communicate them to others during hazard review meetings?

This question measures the effectiveness of the interactive map in helping multi-agency teams capture experience, intelligence and research data and in communicating concerning them to others during hazard review meetings. This included an evaluation of the effectiveness of data obtained from past events and the data obtained from research for multi-agency teams in prioritising hazards in a local area.

Step 3: Risk analysis

Question 6: Does the interactive map help multi-agency teams estimate the likelihood, outcome and impact of hazards in the local area?

This question measures the effectiveness of the interactive map in helping multi-agency teams estimate the likelihood, outcome and impact of hazards in the local area. This relates to how the interactive map allows multi-agency teams to estimate the likelihood of a hazard occurring and how well the map allows teams to model, for example, the number of people and the amount of critical infrastructure that would be affected (impact) by a hazard according to the size, scale and location of an event (outcome).

Step 4: Risk evaluation

Question 7: Does the visualisation on the interactive map help multi-agency teams to collaboratively identify and prioritise risk hotspots in the area to produce a risk matrix (very high, high, medium and low)?

This question measures the effectiveness of the interactive map in helping multi-agency teams to collaboratively identify and prioritise risk hotspots in the area to produce a risk matrix. The evaluation investigated the extent to which the interactive map is effective in providing a holistic view of the local area, which enables multi-agency teams to identify and prioritise risk hotspots in the local area.

Step 5: Risk treatment

Question 8: Does the visualisation on the interactive map help multi-agency teams to collaboratively understand their current capabilities to treat risks and to identify gaps in these capabilities?

This question measures the effectiveness of the interactive map in helping multi-agency teams to collaboratively understand their current capabilities to treat risks and to identify gaps in these capabilities. This relates to how well the interactive map allows members of multi-agency teams to share the location and level of their resources which could be used in the event of a disaster.

Step 6: Monitoring and Reviewing

Question 9: Does the interactive map help multi-agency teams to collaboratively update, review and maintain information regarding local risks?

This question measures the effectiveness of the interactive map in helping multi-agency teams to collaboratively update, review and maintain information regarding local risks. This relates to how well the interactive map allows members of multi-agency teams to monitor risks continuously and to repeat the previous steps (1 -5) when new risks are identified.

Second Aspect: perceived effectiveness of the potential of the interactive map for strengthening the collaboration between multi-agencies.

This aspect assesses the interactive map's perceived effectiveness for strengthening the collaboration between multi-agencies. Rather than specific risk assessment activities, a number of questions were included to capture how well the interactive map enhances the collaboration, decision-making, communication and coordination of multi-agency teams. This involved questions relating to numerous sub-skills, including the extent to which the interactive map enhances group reasoning, interpretation and assessment skills and the interactive map's enhancement of a team member's ability to express their views, ideas, information and agendas. Moreover, the responses to questions which were included to explore how well the interactive map enhances the reasoning, assessment and interpretation skills of team members were also evaluated in the context of the complex situations multi-agency teams encounter in the area of risk assessment.

8.2.2 Assessment Criteria

The assessment criteria relate to the role of the interactive map prototype in supporting risk assessment process activities and the interaction and collaboration of multi-agency decision makers. The following are the two aspects that were tested during the evaluation:

- Perceived effectiveness of the interactive map in supporting the risk assessment process
- Perceived effectiveness of the interactive map for strengthening the collaboration between multi-agencies.

8.2.3 Assessment Setting

8.2.3.1 Experimental Platform

The experiment involved the use of the prototype of interactive map that was described in detail in Chapter 6. As previously noted, the prototype presents a mapping area, based on a Google Earth plugin and a contextual menu. The map can be overlaid with layers of social information, natural information, infrastructure, hazardous site, resources and flood information, which users can toggle between and combine. To navigate through the map a mouse was used. The design of the platform provides a collaborative environment, open to all users. The environment is viewed on a single, large screen. Team members interact within this environment, coordinated by a presenter.

The prototype interactive map was populated with data sets from a variety of sources. The locations of infrastructure, such as roads, railway lines and bridges, were already mapped. Some of the data, such as information on hazardous sites was randomly generated, while some of the social information came from existing projects undertaken by housing associations. Historical data, relating to a flood in the area in 1947, was also used to populate the prototype. As only a prototype was being produced, the focus was on generating a hypothetical situation rather than a completely accurate one which would have been time consuming and for which it would have been difficult to gather the required information.

8.2.3.2 Pilot Study

In order to test the quality and effectiveness of the evaluation study a "pilot" study was organised to check whether the interactive map prototype was functional, the scenario was clear and the questionnaire was going to work effectively. The pilot study helped to find out whether the questionnaire was rational, to find out whether its instructions were clear, to remove questions that did not add usable data and to test the total time needed to complete the questionnaire. Four subjects took part in the pilot study before the final user evaluations were conducted. The evaluation tasks and the questionnaire were refined and revised based on the outcome of the pilot study.

8.2.3.3 Think Lab Setting

The experiment took place in the Think pod in Think Lab, The University of Salford (pictured below Figure 8. 2). The Think Lab was created specifically for the purpose of exploring collaboration and multi-disciplinary thinking. The Think pod is a room specifically designed for collaboration, multi-disciplinary thinking and innovation. It has a focused layout, with chairs arranged in a horseshoe shape facing a large digital screen. This allows participants to see each other, to interact face-to-face and to view the interactive map on the large screen. Each chair is equipped with a small desk, allowing participants to make notes.

Figure 8. 2: The Think pod

8.2.3.4 Subjects

The subject group in the experiment was made up of stakeholder senior managers involved in the Greater Manchester Resilience Forum Development Group. The experiment was held in the Think pod in the Think Lab, the University of Salford. A total of 23 subjects took part in the evaluation experiment. The interactive map prototype was presented to members of this group which consisted of professionals from the University of Manchester, the Department of Communities and Local Government, the Ministry of Defence, British Transport Police, GM Fire and Rescue Service, the Association of Greater Manchester Authorities, GM Police, United Utilities, the North West Ambulance Service, the Highways Agency, Public Health England, the NHS, Transport for GM, the Environment Agency, BT and the Radio Amateur's Emergency Network. After seeing the demonstration, participants gave their feedback using a questionnaire that included both open and closed questions, rating scales and observation.

8.2.4 Data Collection Methods

The approaches applied in this evaluation were a workgroup discussion and a questionnaire. In this experiment, the workgroup approach involved the participants being recorded while being presented with the interactive map and then discussing it as a group. To capture their feedback at this stage, video and voice recording were used as the participants had their discussion. The recordings were later used to analyse the collected data (Spagnolli et al., 2003).

In addition, a questionnaire was employed. The purpose of this exercise was to give individual participants the opportunity to express their preferences and opinions privately after the group discussion. These questionnaires included open and closed questions, rating scales and multiple-choice questions (Patel et al., 2006). The questionnaire method was selected on the basis that such a format focuses participants' answers on very specific aspects of the evaluation. This is in contrast to other formats, which are good at providing general opinions but not as effective at gathering the specific data needed to evaluate a prototype like this in sufficient depth (Remenyi et al., 1998; Easterby-Smith et al., 2008). The open questions were specific, but allowed participants a chance to express opinions in a degree of depth, while the closed questions restricted their responses to a scale of satisfaction. This combination balanced the need for specific, quantifiable data with the usefulness of more open, qualitative data. Questions were related to each of the six stages of the risk assessment process and all focused on the extent to which the interactive map prototype enhances multi-agency collaboration in risk assessment.

The rationale behind using these methods is that they combine together to provide the most useful data. The questionnaire method provided specific, restricted data. It was supported throughout the evaluation by the observation method allowing the participants to give feedback on the interactive map system. This method allowed participants to provide more open, free feedback than the tightly controlled feedback they gave in the questionnaire. As a result, the approach followed in this research combined the advantages of questionnaires and the advantages of a workgroup, with each making up for the other's shortcomings.

8.3 Procedure of the Experiment

The next section describes the evaluation process of the experiment, beginning with the briefing of the subjects, the demonstration they received of the system prototype, the appointment of a chair person to lead the group of participants (before describing the flood scenario the participants were presented with), the group discussion that followed and the distribution of the paper questionnaires.

8.3.1 Subject Briefing

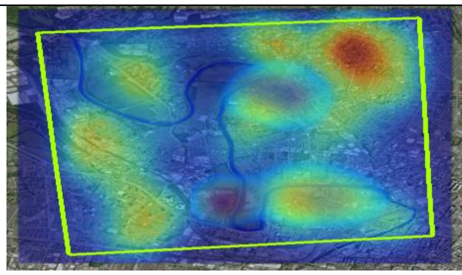
In order to maximise the validity and reliability of the findings of the research, a number of steps were taken. Firstly, the participants were given a summary of the objectives of the experiment in order to ensure that they understood the experiment and its context.

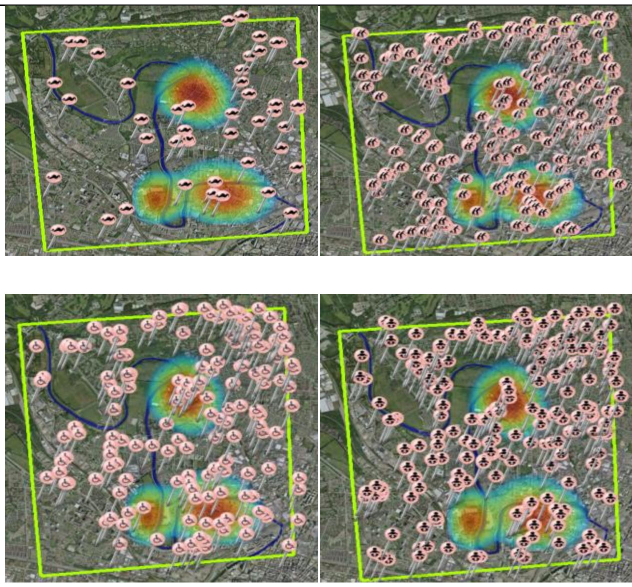
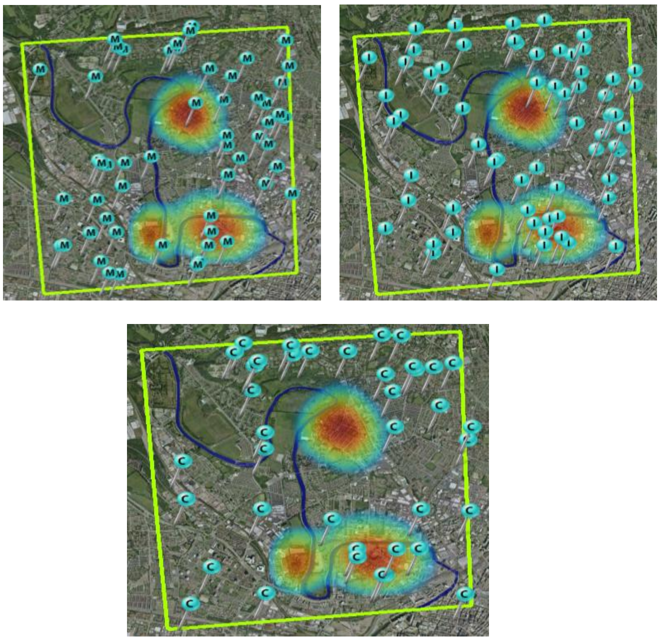
Secondly, all participants received a consent form explaining that they could withdraw from the study at any time and that their data would be stored indefinitely. This ensured that the participants gave fully informed consent to participate. An important aspect of the experiment was the commitment to maintain the anonymity of the participants, in order to allow for the participants to freely express their opinions. To do this, on the day of the experiment, each participant was given a number while they were receiving their consent form, objectives' summary and questionnaires. Participants also received an identity badge showing the agency from which they came. This enabled the researcher to be aware of their background when responding to any queries/request for guidance.

8.3.2 Demonstration of the Capability of the System

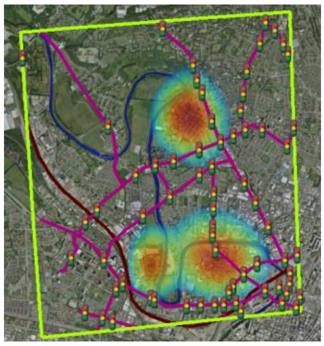
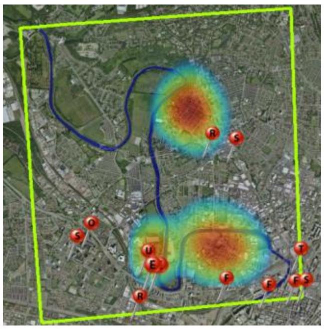
The teams of participants were given a demonstration of all the aspects of the interactive map prototype. They were shown all the information included in the prototype, including all of the themes, categories and subcategories available on the contextual menu. Firstly, they were shown the flood visualisation theme and its related categories and subcategories. Secondly, they were shown the social information theme and its related categories and subcategories. Next, they were shown the natural environment theme and its related categories. Subsequently, the infrastructure theme and its related categories and subcategories were demonstrated. Then the hazardous sites' theme and its related categories were demonstrated. Finally, the resources theme and its related categories were shown before the user defined data theme and its related categories were shown. Participants were then shown how the contextual menu allows users to select different categories and subcategories, switch between points and heatmaps for some layers and to add and remove different layers of information. The goal of this stage of the experiment was to give subjects a full understanding of the interactive map prototype and how it could be populated with various kinds of information, how this information is visualized and how this information can be combined. Table 8. 1 below summarises the type of information demonstrated.

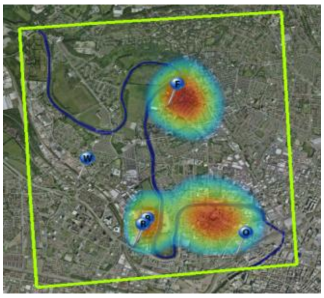
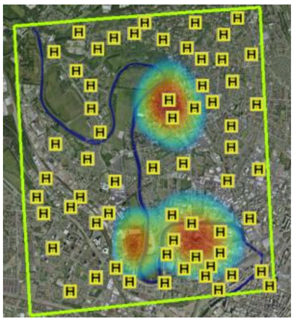
Table 8. 1: A summary of the type of information demonstrated

Type of information demonstrated		Visualisation
Flood visualisation	• Study area • River • Historical flood data	
Social information	• Demographics 1. Population densities	
	• Community 1. Ethnic communities who are not well integrated with society in general and have language difficulties 2. A transient population (travellers' communities, students)	

	• Mobility needs 1. Elderly people 2. People with disabilities 3. Families with children (infants) 4. Pregnant ladies	
	• Health care needs 1. Serious medical needs (requiring specialist medical equipment for evacuation) 2. Specific types of illnesses (needing special procedures for evacuation) 3. Those with chronic health conditions	
	• Building hosting vulnerable people 1. Hospices 2. Schools	

Natural Environment	• Reservoirs • Area with risks of landslide • Rivers • National parks • Forests • Animal sanctuaries	
Infrastructure	• Utility services (hubs) 1. Electrical Substations (Electricity supply networks, Electricity transformers) 2. Telecom substations (Telecom supply networks, Green boxes, Mobile phone towers and masts, Premises containing data hubs of communications centres) 3. Gas substations (Gas supply networks) 4. Water distribution points	

	• Transport 1. Bridges 2. Rail network 3. Road network 4. Major roads 5. Traffic lights	 
	• Buildings 1. Major financial institutions 2. Shopping centres 3. Health buildings; GPs hospitals & pharmacists 4. Residential houses 5. Buildings of interest; police, ambulance & fire stations 6. Heritage buildings & sites 7. Universities	  

Hazardous Sites	• Waste disposal sites • Chemical factories • University labs (biological & biometric)	   
Resources	• Fire Hydrants • Firetrucks • Ambulances	  

8.3.3 Appointment of a Chairperson and Description of the Flood Scenario

A chairperson, who had been appointed before the experiment, then began to manage the experiment. The chairperson was a local agent who had acted as a chairperson previously. She worked for Local Resilience Forums to support collaboration at the local level. The chair briefed the participants on the purpose of the experiment and presented the flood scenario to them. The flood scenario involved a hypothetical report of heavy rain from the Met Office which was used as a basis to simulate flooding in three locations. Visualisations of the flood scenario and the location of elderly and disabled people were then shown. Next, critical infrastructure (electricity substations, telecommunications, major roads and traffic lights) was visualized on the map, as well as the areas that would be affected by the failure of this infrastructure. Hazardous sites and their affected areas (in the event of a flood) were then visualized, before the locations of fire and ambulance services' resources were displayed. A screen shot of the flood scenario within the interactive map is shown in Figure 8. 3: A screen shot of the flood scenario within the interactive map Figure 8. 3.

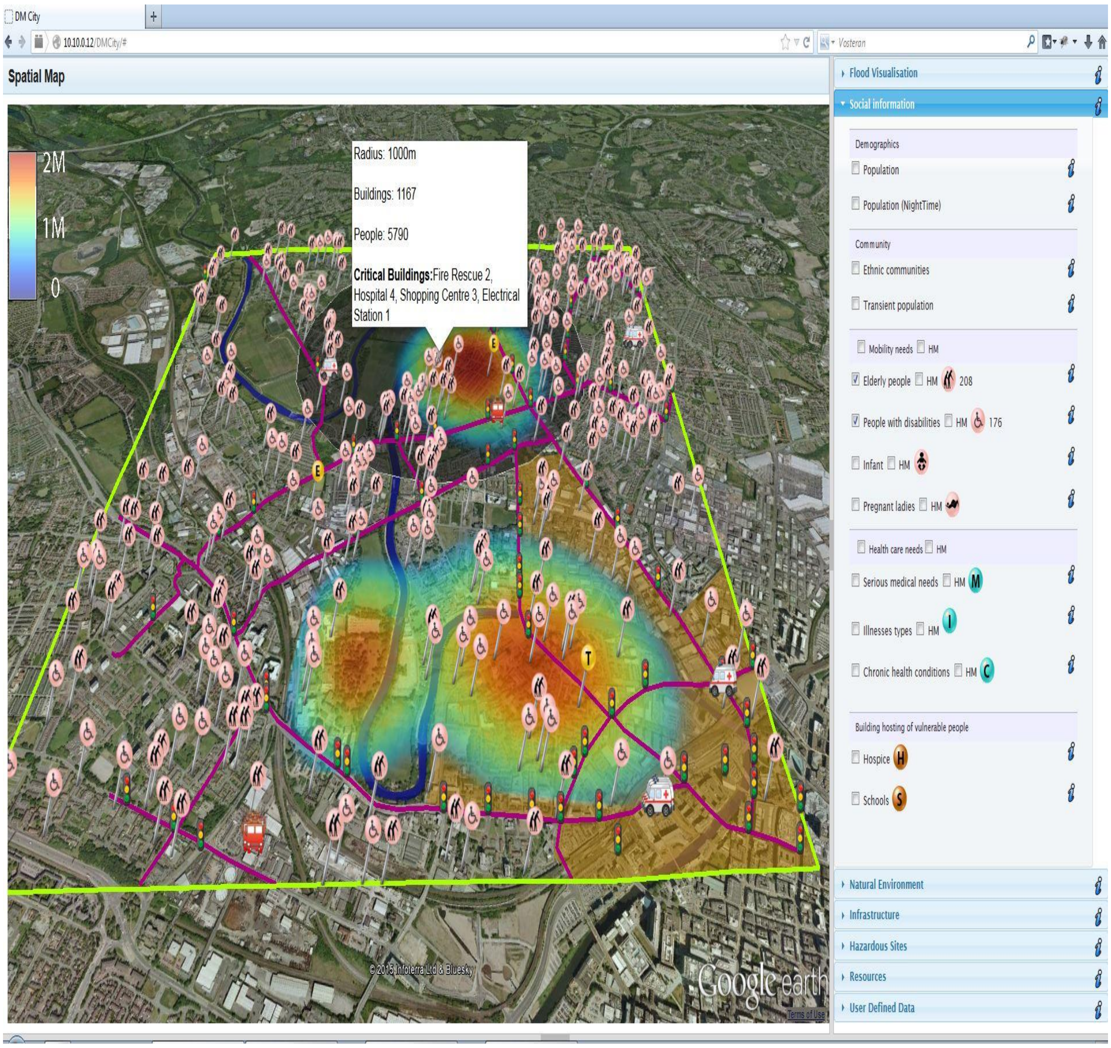


Figure 8. 3: A screen shot of the flood scenario within the interactive map

The scenario presented is realistic from a number of angles. Firstly, the participants are real fire-fighters, policemen, a real local authority etc. and it involves workers from different agencies. Secondly, the sites are real and they represent real-world places and areas. Thirdly, the locations of fire and ambulance services' resources were displayed. Fourthly, the participants' responses and reactions are also real because they have experience in dealing with situations similar to the one visualised on the interactive map. Every element in the experiment is real apart from the utilisation of a flood scenario which has to be created based on the historical data to find out the participants' responses and comments.

8.3.4 Discussion on the perceived effectiveness of the Interaction Map Prototype

With this scenario established, the team of participants was shown a screen displaying the six stages of the risk assessment process. This was intended to remind the subjects of the process and to encourage them to keep it in mind while they discussed the usefulness of the prototype. Led by the chairperson, they were asked to discuss, as a group, the value of the prototype. They were asked to discuss the extent to which the interactive map would enhance risk assessment activities. A whole group discussion was conducted so as to reflect real-world multi-agency collaboration. Firstly, the chair instructed the participants to discuss the perceived effectiveness of the prototype in the contextualization of social information (vulnerable people, demographics), critical infrastructure (electricity substations, telecommunications stations and major roads), the natural environment (reservoirs, areas with possible risks of landslides, rivers, animal sanctuaries), hazardous sites (the locations of chemical factories, university labs (both biological & biometric)). Secondly, the chair instructed the subjects to discuss the value of the prototype at the hazard review stage. Participants discussed the scenario they had been given and the usefulness of the interactive prototype in prioritising hazards in this scenario. Thirdly, the chairperson told the subjects to discuss the perceived effectiveness of the interactive map at the risk analysis stage. Participants discussed the usefulness of the interactive map in estimating the outcome and impact of the hazards in the scenario. Next, subjects were asked by the chairperson to discuss the value of the prototype at the risk evaluation stage. Participants discussed how the interactive map could be used to collectively identify and prioritise risk hotspots in the scenario's study area. Subsequently, the chairperson instructed subjects to discuss how useful the interactive map would be in risk treatment activities. Subjects then discussed how they would use the resources available in the scenario. Finally, participants were led in a discussion on the perceived effectiveness of the prototype in monitoring and reviewing risks continuously and in repeating the previous steps (1 -5) stage of the risk assessment. Throughout this process, participants were encouraged to share their views and insights.

Following this discussion, participants were given an individual paper questionnaire to complete and submit by the end of the experiment. Giving a paper questionnaire meant that participants could express their views privately using the questionnaire if they did not want, or did not feel able, to publicly share them in the discussion, thus increasing the reliability of the data collection.

8.4 Summary

The methodology employed to evaluate the interactive map system aimed to investigate its ability to support collaboration and enhance multi-agency teams' activities in the risk assessment process. The employed methodology was divided into two areas of evaluation. Firstly, the perceived effectiveness and impact of the visualisation on the interactive map on risk assessment processes and, secondly, the perceived effectiveness of the visualisation on the interactive map for a successful interactive and collaborative environment were evaluated. This evaluation was achieved by using the system to demonstrate layers of information relating to a flood scenario. The scenario was based on historical data and the layers of information demonstrated to participants were layers showing social information, natural information, infrastructure, hazardous site, resources and flood information. 23 participants from the Greater Manchester Local Resilience Forum Development Group attended the experiment in the Think pod, within Salford University's Think Lab. They were given consent forms, a summary of the objectives of the study and identity badges. The data they provided were kept anonymous. After viewing a demonstration of the system, participants were asked to discuss the platform and the scenario it presented as a group. The researcher observed this discussion, enabling the capture of freely given feedback. Subsequently, questionnaires which combined open, closed and rating scale questions were given to the subjects to capture more specific qualitative and quantitative feedback. The next chapter presents the evaluation results collected during the evaluation experiment of the interactive prototype.

Chapter 9 – Analysis of the Evaluation Results

9.1 Introduction

The purpose of this chapter is to present the evaluation results collected during the evaluation experiment described in the previous chapter. Given that the strategy, which has been followed for this research work, is the interpretivist stance, the data collected from work group discussions and the open and closed ended questions were analysed qualitatively. However, some of the data that was collected from the rating scale questions was manipulated statistically for descriptive analysis. The outcome of the analysis process of the data was used to measure the 'perceived effectiveness' of (1) the potential of the interactive map in supporting risk assessment processes, and (2) the potential of the interactive map for strengthening the collaboration between multi-agencies.

9.2 Perceived effectiveness of the potential of the Interactive Map in supporting Risk Assessment Processes

The first aspect (perceived effectiveness of the potential of the interactive map in supporting risk assessment processes) covers the stages of the risk assessment process. This includes questions on the following: Firstly, contextualization activities related to understanding social, natural, and infrastructural and hazard site risks in an area. Secondly, Hazard Review activities related to the identification of significant risks the based on experience, historical data, research or other information. Thirdly, Risk Analysis activities related to assessing the outcome and impact of a local risk. Fourthly, Risk Evaluation activities related to the identification and prioritization of local risk hotspots. Finally, Risk Treatment activities related to the identification of a multiagency team's existing capabilities and the identification of gaps in the capabilities available. This part of the evaluation aimed to identify the extent to which the interactive map prototype enhances multi-agency teams' understanding of local risk information, their discussion of this information and their collective-decision based upon it. It also aimed at evaluating the information that the system makes available and how well the system enhances collaboration throughout the risk assessment process. This process was broken into steps and sub-steps, which were analysed in turn.

Step 1: Contextualization of Local Risk

Step 1 comprised the use of contextual information of the following types: social information, natural environment information, local infrastructure information and hazard site information.

A. Contextualization of Social Information (CSI)

The following statements were asked in order to evaluate the perceived effectiveness of the Visualization of Social Information on the interactive map:

U1a1. The visualization of this social information on the interactive map helps multi-agency teams collectively understand local social risks.

U1aa. The visualization of social information helps multi-agency teams understand areas in the city where the vulnerable are concentrated.

U1ab. The visualization of social information helps multi-agency teams understand the demographic, ethnic and socio-economic composition of the community.

U1ac. The visualization of social information helps multi-agency teams understand the geographical location of various communities within the local area.

U1ad. The visualization of social information helps multi-agency teams understand the level of preparedness required for coping with demands arising from a potential disaster.

U1ae. The visualization of population densities helps multi-agency teams place resources that can be used to evacuate residents.

U1af. The visualization of population changes over daytime/night time helps multi-agency teams understand the varying demands in evacuation planning.

U1ag. The visualization of ethnic communities who are not well integrated with society helps multi-agency teams identify community leaders who could be used to warn and inform their communities during emergencies.

U1ah. The visualization of a transient population (travellers' communities, students) helps multi-agency teams to identify and safeguard those communities during emergencies.

Table 9. 1: Statistical summaries from the evaluation of the Visualisation of Social Information on the interactive map

	U1a1	U1aa	U1ab	U1ac	U1ad	U1ae	U1af	U1ag	U1ah
Min	1	1	2	2	1	2	1	2	1
Median	4	4	3	4	3	3	4	4	3
Max	5	5	5	5	5	5	5	5	5
Mean	3.82	4.08	4	3.86	3.17	3.6	3.73	3.39	3.26

* Min – minimum, Max – maximum

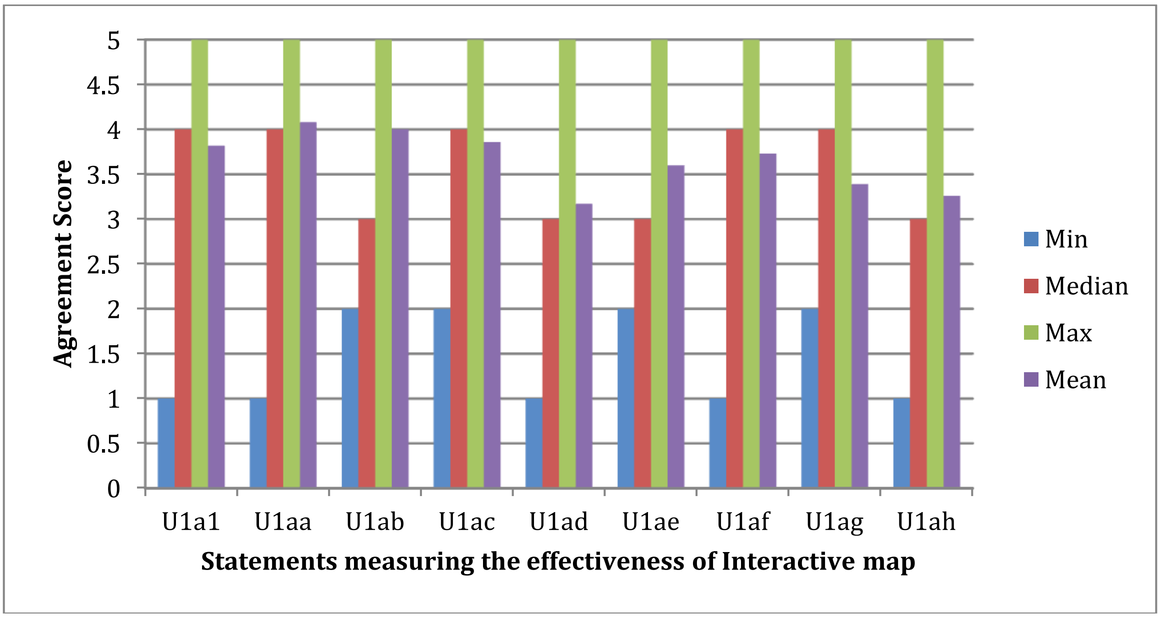


Figure 9. 1: Clustered columns showing the distribution from the evaluation for the Visualisation of Social Information on the interactive map

Table 9.1 and Figure 9.1 show the statistical summaries of the participants' evaluation of the visualization of social information. On average, participants rated the social information provided by the interactive map to be good to excellent. The interactive map's information relating to the concentrations of socially vulnerable people and its provision of demographic and ethnic information were rated particularly highly with an average of 4. For instance, Participant 7 suggested that this kind of information is useful for identifying possible "tensions within diverse communities" (GM Police). This was described in more depth by a participant, who claimed that: "Communication (with members of a community) could be concerned with language but could also be about what the tensions are in that area. So if we go in saying 'come on now we're evacuating' and they just turn around and start turning guns on us". However, the interactive map's ability to help users understand the level of preparedness required was rated lower, at an average of 3.17. Participant 8 suggested that the data should be simplified to prevent users becoming confused by too much information: “maybe to the point of (only including) population density, schools’ and hospital data” (United Utilities plc). On the other hand, Participant 17 claimed that multi-agency teams would benefit if the interactive map also showed the “mapping of social media/internet usage to help in determining the best methods of communciation with the public in emergencies” (GM Police). With this feedback established, all of the mean average scores for the statements relating to social information produced a rating of good satisfiaction.

In terms of social information, the author takes the view that the interactive map should provide relatively simple social information. Providing data about population density and the locations of vulnerable people are the most useful for multi-agency decision makers. While they are well-intentioned, the suggestions of some of the participants that the interactive map could include information about internet and social media use or tensions between members of a community and the authorities are impractical. As each client requires different levels of detailed information, it is not feasible for an interactive map to include everything that would potentially be useful without it becoming too complicated and, therefore, difficult to use.

B. Contextualization of Local Infrastructure (CLI)

The following statements were asked in order to evaluate the perceived effectiveness of the Visualization of Local Infrastructure Information on the interactive map:

U1b2. The visualisation of such local infrastructure information on the interactive map helps multi-agency teams to collectively understand local infrastructure risks.

U1ba. The visualisation of electrical substation locations and associated colour map helps multi-agency teams understand the number of buildings that would be affected by the loss of a substation.

U1bb. The visualisation of telecom substation locations and associated colour map helps multi-agency teams in determining the impact on buildings in the event of the loss of a telecommunication substation.

U1bc. The visualisation of water distribution point locations and associated colour map helps multi-agency teams identify how many buildings and key infrastructures would be affected by the lost of such a water distribution point.

U1bd. The visualisation of health facility locations helps multi-agency teams identify the health facilities that could be used in emergency situations.

U1be. The visualisation of heritage buildings & similar sites' locations helps multi-agency teams to identify which of these are more vulnerable to risk and to consider protection measures.

U1bf. The visualisation of major financial institution locations helps multi-agency teams identify critical financial institutions that could be placed in a vulnerable situation.

Table 9. 2: Statistical summaries from the evaluation of the Visualisation of Local Infrastructure on an interactive map

	U1b2	U1ba	U1bb	U1bc	U1bd	U1be	U1bf
Min	1	1	1	2	2	2	2
Median	5	5	5	5	4	4	4
Max	5	5	5	5	5	5	5
Mean	4.04	4.3	4.04	4.13	4.13	3.82	3.73

* Min – minimum, Max – maximum

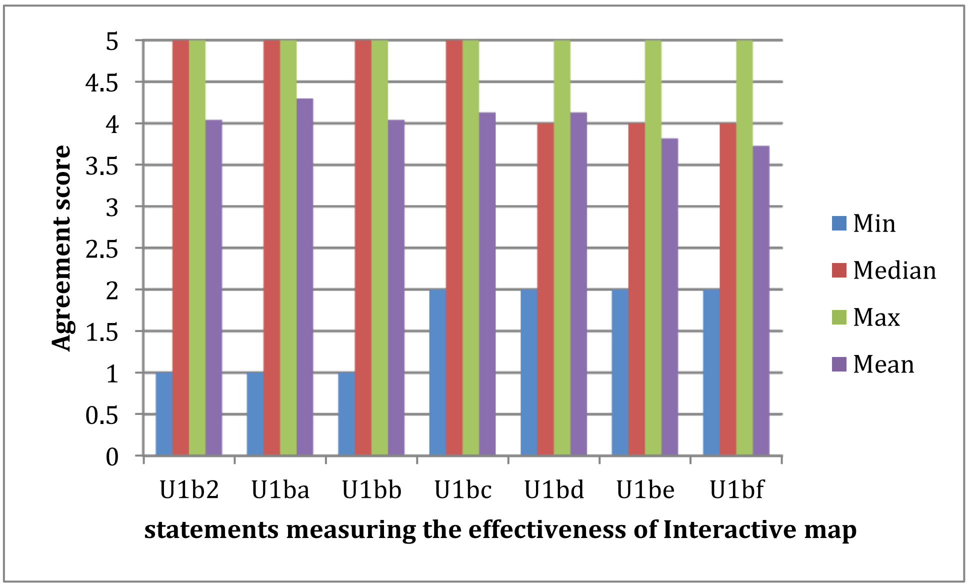


Figure 9. 2: Clustered columns showing the distribution from the evaluation for the Visualisation of Local Infrastructure on an interactive map

Table 9.2 and figure 9.2 show the statistical summaries of the participants' evaluation of the visualisation of local infrastructure information. On average, participants rated the infrastructure information highly, with most areas receiving excellent satisfaction. The only statements to receive less than a mean average score of 4 were statements relating to the information provided on vulnerable financial institutions and heritage sites. However, the median score of each of the statements was between 4 and 5 and the overall usefulness of the infrastructure information was noted by one participant who stated that:

"I get it in terms of infrastructure because it is pretty solid. You've got that data. You can usually use that." However, Participant 10 was more critical of the system, suggesting that: "currently it does not reflect the 'knock on' consequences of certain infrastructure being impacted". The need for the interactive map to visualise cascading effects was noted by a participant who, in the discussion, suggested: "As the level (of rainfall) is going up I'd be looking at what's tipping over as a result of that heavy rainfall… If the electricity substation closes down, what happens? Then what happens to the local fire station? Etc." (Highways Agency).

Here, the author believes that the interactive map prototype's visualisation should show the critical infrastructure that would have the biggest impact if affected, such as electricity, gas and telecommunication substations and water distribution points. Moreover, it should definitely include major roads because these are vital in dealing with disasters when they happen. The cascading effect needs to be modelled using different modelling technologies such as system dynamics and the Bayesian belief function. Once modelled the result could be incorporated into the map.

C. Contextualization of the Natural Environment (CNE)

The following statements were presented in order to evaluate the perceived effectiveness of the visualisation of natural environment on the interactive map:

U1c3. The visualisation of the Natural Environment on the interactive map helps multi-agency teams establish a collective understanding of the important natural resources within the space viewed.

U1ca. The visualisation of reservoir locations helps multi-agency teams assess and understand the area that would be affected by a potential dam failure.

U1cb. The visualisation of animal sanctuary locations (and the type and number of animals there) helps multi-agency teams understand the numbers and types of animals that need rehousing.

U1cc. The visualization of national park locations helps multi-agency teams understand the impact that a disaster could have on plants, wildlife and on sites of special environmental interest.

Table 9. 3: Statistical summaries from the evaluation of the Visualisation of the Natural Environment on an interactive map

	U1c3	U1ca	U1cb	U1cc
Min	2	2	2	2
Median	4	5	4	4
Max	5	5	5	4
Mean	3.78	4	3.65	3.56

* Min – minimum, Max – maximum

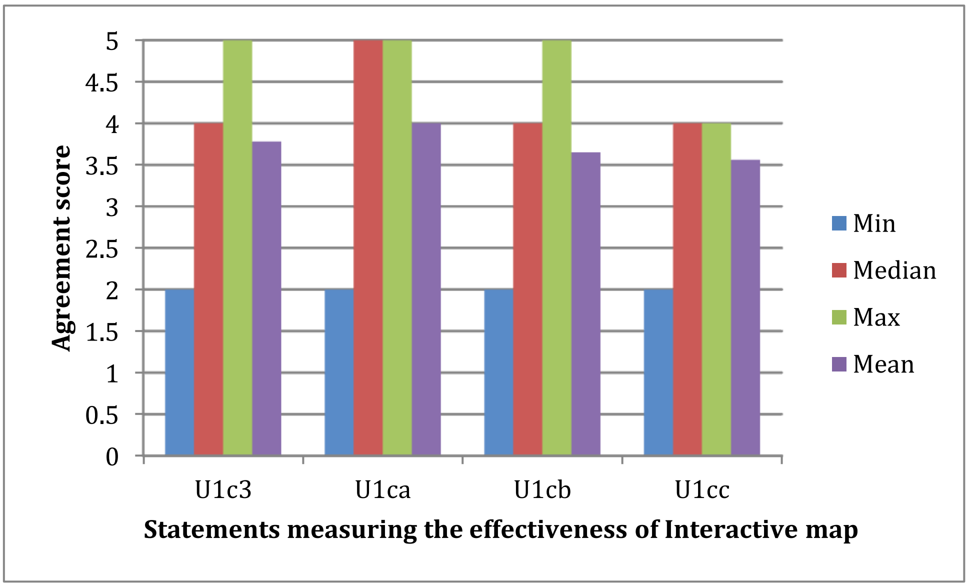


Figure 9. 3: Clustered columns showing the distribution from the evaluation for the Visualisation of the Natural Environment on an interactive map

Table 9. 3 and Figure 9. 3 show the statistical summaries of the participants' evaluation of the visualisation of the natural environment information. The mean average score for each statement corresponds to a good level of satisfaction and the median score for all the statements was between 4 and 5. The statement that received the highest mean average score related to the interactive map's information about reservoirs, while the statement with the lowest mean average score related to the map's provision of national park information.

In this area, the author assumes that the information provided by the interactive map should be prioritised according to its relevance to the protection of the public and property. The most obvious examples of natural environmental information to map include the locations of reservoirs and rivers. Natural information could also include, for example, forests that could catch fire, or zoos and the types of animals they house. While including information about the location of rare species of plants or animals would be useful in order to protect them, this needs to be managed carefully in order to avoid overloading decision makers with information that might not be of great importance to them in an emergency situation that threatens human life.

D. Contextualization of Hazardous Sites (CHS)

The following statements were asked in order to evaluate the perceived effectiveness of the Visualisation of Hazardous Sites on the interactive map:

U1b4. The visualisation of such hazardous sites' information on the interactive map helps multi-agency teams to collectively understand the local risks imposed by the sites.

U1ba. The visualisation of chemical site locations and the identification of the number of people that could be affected by hazards occurring on these sites helps multi-agency teams identify people living in proximity to a chemical site in order to communicate with, and inform, them.

U1bb. The visualisation of university lab locations helps multi-agency teams understand the types of material being used on these sites and the potential impact during a disaster.

Table 9. 4: Statistical summaries from the evaluation of the Visualisation of Hazardous Sites on an interactive map

	U1b4	U1ba	U1bb
Min	2	3	2
Median	5	5	5
Max	5	5	5
Mean	4.13	4.21	3.6

* Min – minimum, Max – maximum

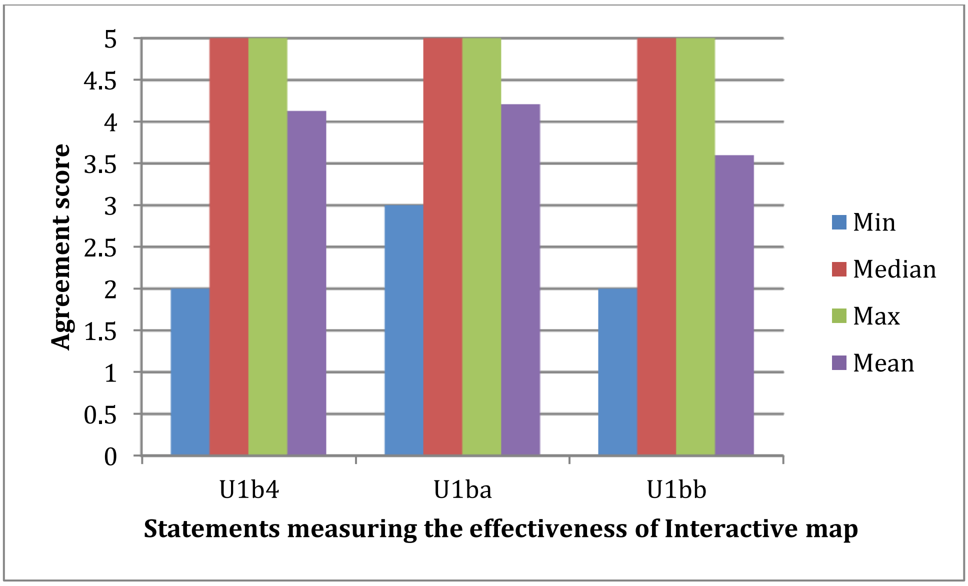


Figure 9. 4: Clustered columns showing the distribution from the evaluation for the Visualisation of Hazardous Sites on an interactive map

Table 9. 4 and Figure 9. 4 show the statistical summaries of the participants' evaluation of the visualisation of hazardous sites' information. Responses were generally positive, with all statements receiving a median score of 5, suggesting an excellent level of satisfaction. Participants suggested that the system would support current risk assessment activities "in terms of… COMAH" sites (GM Fire and Rescue Service, Environment Agency, Association of Greater Manchester). In terms of mean average scores, the only statement to receive less than a mean average of 4 related to the interactive map's visualization of the numbers of people living in the vicinity of a hazard site, which averaged 3.6.

The author views the location and in-depth information about the nature of COMAH sites as being vital to an interactive map system because these sites pose significant risks and need to be approached in different ways and with different equipment depending on the type of site.

9.2.1 Contextualization Average Result

The overall average scores for each task are summarized below, based on the evaluation of each type of topic.

Table 9. 5: Statistical Summaries from the evaluation on the Contextualization of Local Risk

	Contextualization of Social Information	Contextualization of Local Infrastructure	Contextualization of the Natural Environment	Contextualization of Hazardous Sites
Min	1.44	1.57	2	2.33
Median	3.55	4.57	4.25	5
Max	5	5	4.75	5
Mean	3.65	4.02	3.74	3.98

* Min – minimum, Max – maximum

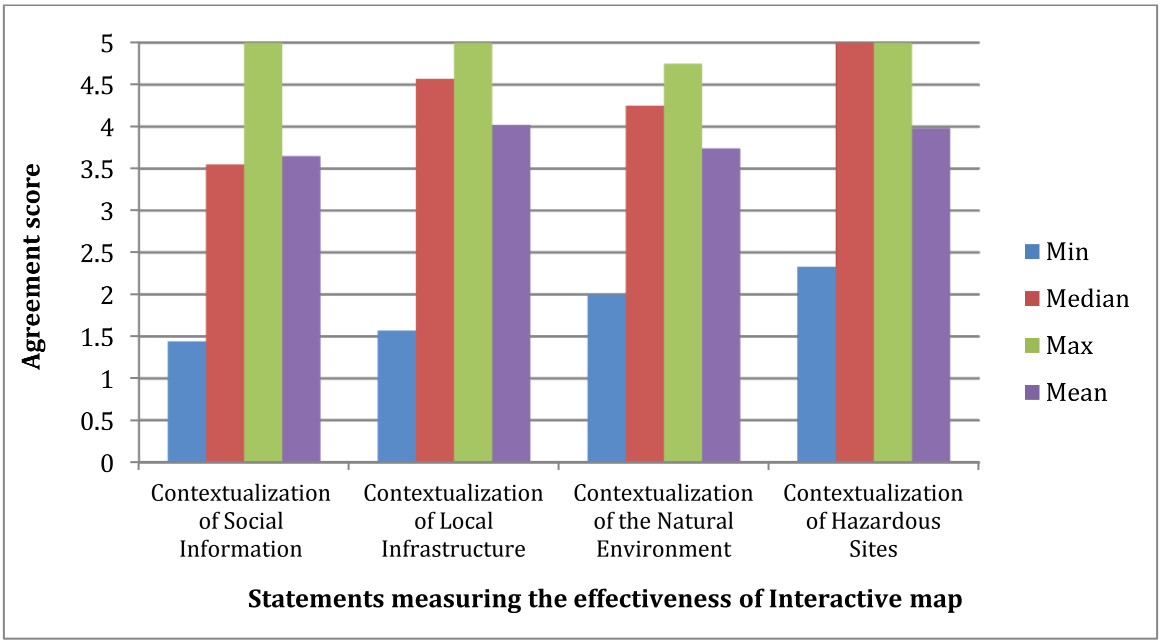


Figure 9. 5: Clustered columns showing the distribution from the evaluation for the Contextualization of local risk evaluation

Table 9. 5 and Figure 9. 5present the statistical summaries of the evaluation of the interactive map for use in the contextualization stage of risk assessment. The highest scoring area, in terms of both median and mean average score, was contextualization of local infrastructure. Statements relating to this area produced a mean average of 4.02 and a median of 4.57. However, the information on hazard sites scored similarly highly on average, with the highest minimum score and a median average of 5. Overall, the results for contextualization suggested a good to excellent level of satisfaction among participants. Therefore, participants were generally satisfied with how the interactive map could support their risk assessment activities. Participant 6 argued that "if data was current and readily available this mapping tool will be very helpful in terms of risk assessment and planning" (Association of Greater Manchester Authorities). The nature of the data included in the interactive map is clearly very important to participants and was

supported by Participant 17 who claimed that the success of the system "would depend on the type and extent of the data" (GM Police). However, Participant 3 suggested that the interactive map visualised too much information, claiming that it could "overwhelm decision makers" (Ministry of Defence). Similarly, Participant 20 claimed that "a system with less information could be more useful and do-able" (BT).

Overall, the author believes that a system which visualises a relatively small amount of important information in way that helps decision makers is preferable to a system which collects a huge amount of information but that, ultimately, is not useable. Moreover, it is vital that careful consideration be given as to what information is included, because it may need to be updated regularly. If this is not possible, then outdated information may be less useful than no information at all. This is particularly relevant to social information, because this information is very changeable. This is in contrast to infrastructure information, which is more fixed and takes longer to alter.

Step 2: Hazard Review (HR)

Hazard review involves multi-agency team members reviewing the contextualization information and, through a process of discussion, identifying the hazards that present significant risks and should, therefore, be assessed further. The following statements were asked in order to evaluate the usefulness of the interactive map for a Hazard Review:

- U25. The interactive map helps multi-agency teams capture experience, intelligence and research data and to communicate them to others during hazard review meetings.
- U2a. The visualisation of past data (such as the impact of previous floodings) helps multi-agency teams understand the impact of similar potential emergencies, and assists in learning from past actions and theexperience of others.

Table 9. 6: Statistical summaries from the evaluation on the perceived effectiveness for Hazard Review of an interactive map

	U25	U2a
Min	1	3
Median	4	4
Max	5	5
Mean	3.56	4

* Min – minimum, Max – maximum

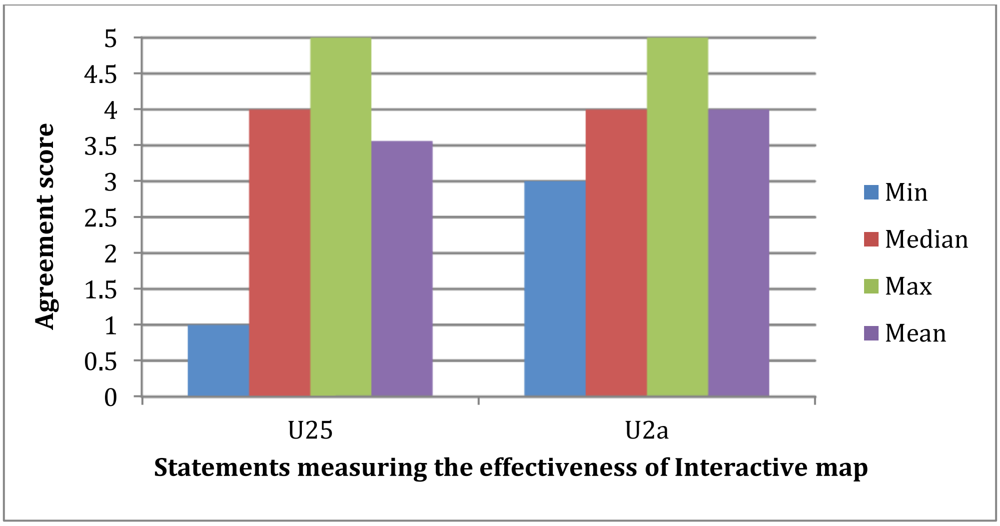


Figure 9. 6: Clustered columns showing the distribution from the evaluation of the usefulness for a Hazard Review of an interactive map

Table 9.6 and Figure 9. 6 show the statistical summaries of the participants' evaluation of the perceived effectiveness of the interactive map in a hazard review. Both statements received median average scores of 4 and maximum scores of 5. However, the first statement, relating to the system's support for the capture of experience, intelligence and research data, attracted a very low minimum score of 1. At 3.56, the first statement's mean score was slightly lower than the second statement, which had the highest mean average of 4. Overall, this suggests good to excellent satisfaction for the use of an interactive map in hazards' review. For example, statement U2a was supported by Participant 3 who claimed that the interactive map is useful in a hazard review "through the display of the impacts and consequences of an emergency event" (Ministry of Defence). Similarly, statement U25 was supported by Participant 1 who praised the "communication" enabled by the system (University of Manchester).

Step 3: Risk Analysis (RA)

Risk Analysis involves multi-agency team members estimating the outcome and impact of hazards previously agreed and using the interactive map to justify their predications on the potential magnitude of the hazards identified (in terms of numbers of people, buildings and critical infrastructure affected). The following statements were asked to evaluate the usefulness of the interactive map for Risk Analysis:

U36. Visualisation on the interactive map helps multi-agency teams estimate the outcome and impact of hazards in the local area.

U3a. The interactive map helps multi-agency teams to collectively understand the outcome of hazards (eg, in the case of a flood, the likelihood of certain hazards occurring and the likely magnitude of such hazards).

U3b. The interactive map helps multi-agency teams to collectively understand the impact of hazards on people, such as the numbers potentially affected by the hazard.

U3c. The interactive map helps multi-agency teams to collectively understand the impact of hazards on critical infrastructure, the number of buildings affected and on utility services and transport.

U3d. The interactive map helps multi-agency teams to collectively understand the impact of hazards on plants, wildlife and on sites of special environmental interest.

U3e. The interactive map helps multi-agency teams to collectively understand the impact of hazards on the economy of the area affected (e.g. the number of shopping centres unable to function because of the loss of electricity due to a substation failure).

Table 9. 7: Statistical summaries from the evaluation on the perceived effectiveness for Risk Analysis of an interactive map

	U36	U3a	U3b	U3c	U3d	U3e
Min	2	2	2	2	2	2
Median	4	4	3	4	3	4
Max	4	5	5	5	5	4
Mean	3.69	3.65	3.78	3.95	3.39	3.39

* Min – minimum, Max – maximum

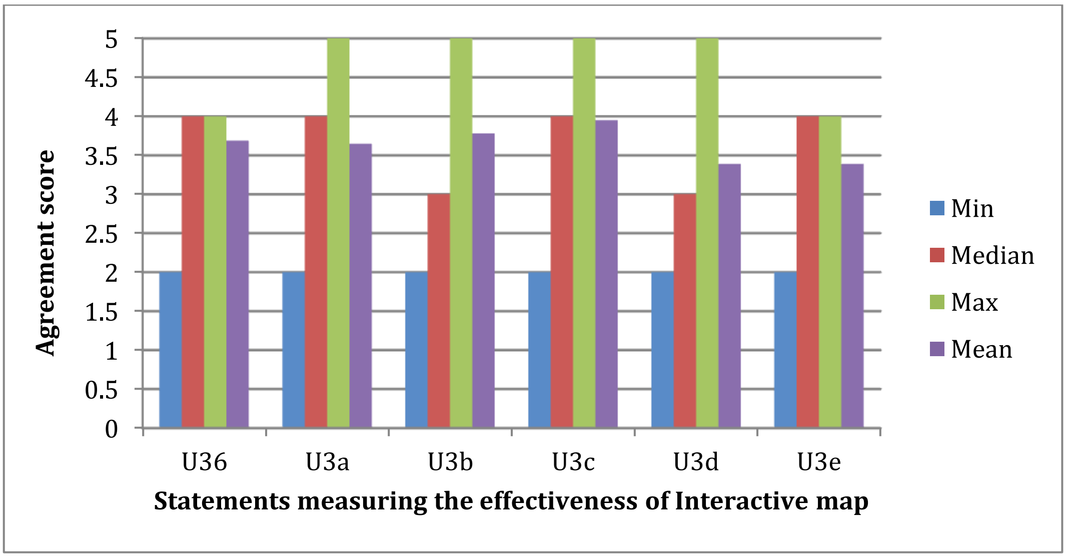


Figure 9. 7: Clustered columns showing the distribution from the evaluation of the effectiveness for Risk Analysis of an interactive map

Table 9.7 and Figure 9.7 show the statistical summaries of the participants' evaluation of the perceived effectiveness of the interactive map in risk analysis. Each of the statements received a mean score corresponding to good satisfaction. U3C received the highest mean average score, at 3.95. Participant 14 suggested that "impact assessment and critical services' mapping would be useful in conducting risk assessment". This suggests that the interactive map is useful in visualising potential impacts on critical infrastructure, the number of buildings affected, and on utility services and transport. The lowest scoring statement in terms of mean average score was U3E, relating to the interactive map's ability to help users understand the economic impact of hazards. This statement attracted a mean average of 3.39. Statement U36, which related to the interactive map supporting users in understanding the outcome and impact of events, received an average score of 3.69 and was supported in comments by participants. Participant 10 claimed that the map "would assist in validating certain assumptions concerning threat impacts" (Highways Agency). In addition, Participant 12 suggested that the map "provides the ability to visually demonstrate different layers of risk and impact" (NHS England) and participant 16 specified the map's ability to depict "cascading/overlapping risk" as an advantage (Association of Greater Manchester Authorities).

Step 4: Risk Evaluation (RE)

Risk Evaluation comprises a multi-agency team collectively identifying and prioritising risk hotspots in an area, producing a risk matrix using a scale of very high to low risk. The following statements were asked to evaluate the usefulness of the interactive map in Risk Evaluation:

U47. Visualisation on an interactive map helps multi-agency teams to collaboratively identify and prioritise risk hotspots in the area in order to produce a risk level matrix (high, medium and low risk).

U4a. The system made it easy to identify risk hotspots in the local area.

U4b. The system made it easy to prioritise these risk hotspots.

U4C. The system made it easy to produce the risk level matrix (showing high, medium and low risk)

U4d. The system made it easy for the group to collaborate on this task.

U4e. The system made it easy to share ideas and to come to an agreement within the group.

Table 9. 8: Statistical summaries from the evaluation on the perceived effectiveness for Risk Evaluation of an interactive map

	U47	U4a	U4b	U4c	U4d	U4e
Min	1	2	2	1	2	2
Median	5	5	4	3	4	4
Max	5	5	4	4	5	4
Mean	3.43	3.91	3.3	3.08	3.47	3.26

* Min – minimum, Max – maximum

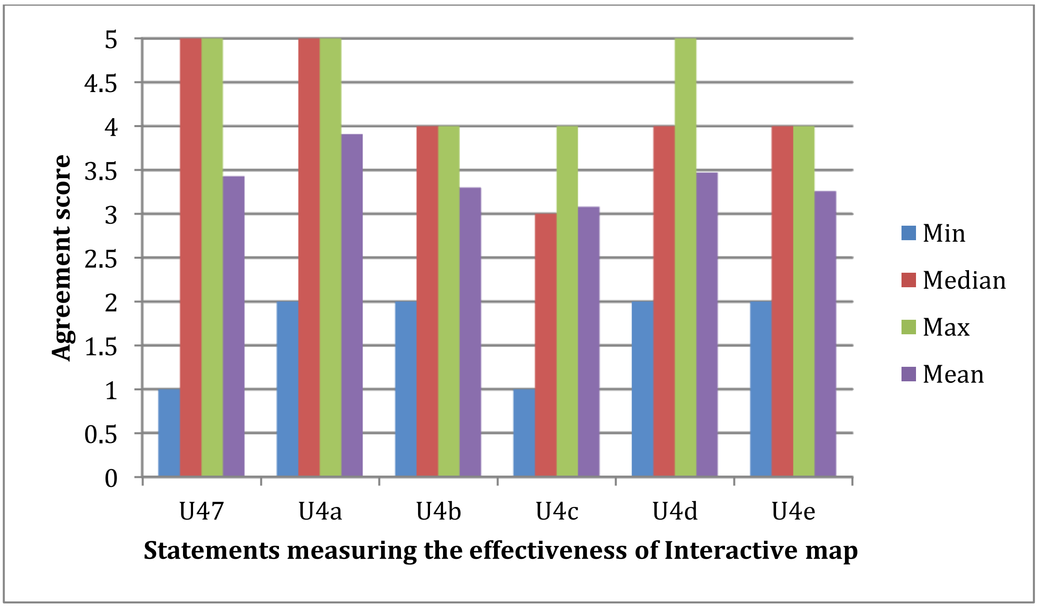


Figure 9. 8: Clustered columns showing the distribution from the evaluation on the effectiveness for Risk Evaluation of an interactive map

Table 9. 8 and Figure 9.8 show the statistical summaries of the participants' evaluation of the perceived effectiveness of the interactive map in risk evaluation. Each of the statements received a mean score corresponding to good satisfaction, all between 3 and 4. The highest mean score was achieved by statement U4A. This is notable because this statement relates to the overall ability of the map to help identify risk hotspots which is the main goal of risk evaluation. Participant 2 suggested that the heat mapping on the system was "particularly helpful" (Dept of Communities & Local Government) and Participant 22 was positive about the interactive map's use for "identifying areas of risks and influence by layering" (GM Fire and Rescue Service). The other statements attracted generally lower mean average scores, with the lowest one, U4C, achieving 3.08. While this still indicates good satisfaction, it does suggest that while the system helps in identifying risk hotspots, producing a risk matrix is not as easy. On the other hand, most of the statements in this stage related to the ease of use which was supported by a number of participants. Participant 7 suggested that the system is "easy to use" (GM Police) and

Participant 9 said that the layers of information were “simple to understand” (North West Ambulance Service). Participant 10 described the system as being “visually easy to interpret” (Highways Agency), while Participant 8 commended the interactiv map for being “user friendly with a clear and concise display of information” (United Utilities plc) and Participant 11 said it is “user friendly and very clear” (Public Health England).

Step 5: Risk Treatment (RT)

Risk Treatment involves a multi-agency team producing a plan for the use of the resources available to them in an area. The following statements were asked to evaluate the perceived effectiveness of the interactive map for Risk Treatment:

U58. The visualisation on the interactive map helps multi-agency teams to collaboratively understand their current capabilities to deal with risks and to identify gaps in these capabilities.

U5a. The system will make it easy to identify the number and the type of resources in the local area.

U5b. The system will help in understanding the overall capability of multi-agencies in the local area.

U5c. The system made it easy to keep track of the use of resources.

U5d. The system made it easy for the group to collaborate on this task.

U5e. The system made it easy to share ideas and to come to an agreement within the group.

Table 9. 9: Statistical summaries from the evaluation on the perceived effectiveness for Risk Treatment of an interactive map

	U58	U5a	U5b	U5c	U5d	U5e
Min	1	1	1	1	1	1
Median	3	4	3	2	3	2
Max	5	5	4	4	4	4
Mean	3	3.3	2.82	2.82	3.17	2.91

* Min – minimum, Max – maximum

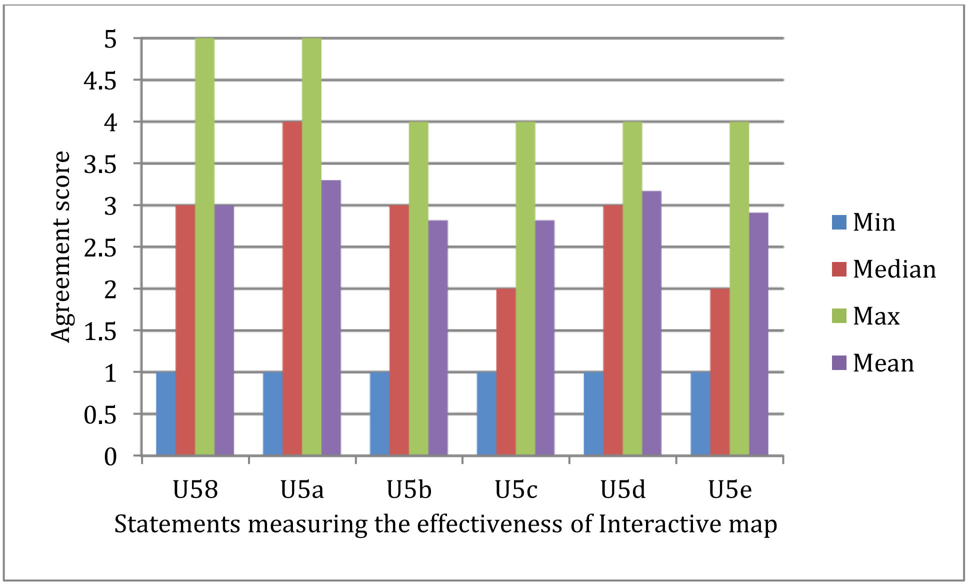


Figure 9. 9: Clustered columns showing the distribution from the evaluation on the effectiveness for Risk Treatment of an interactive map

Table 9. 9 and Figure 9. 9 show the statistical summaries of the participants' evaluation of the perceived effectiveness of the interactive map in risk treatment. Three of the statements suggested good satisfaction while, in contrast, three suggested low satisfaction. The three statements which attracted mean average scores of above 3 related to the overall usefulness of the system in helping to understand the current capabilities and gaps in an area, the map's usefulness in identifying the number of specfic resources available and on the map's ability to promote collaboration. The lower scoring statements, which received scores of 2.82, 2.82 and 2.91, related to the map's usefulness in helping to understand the overall capability, how easily it allows users to keep track of resources and how easily it makes the sharing of ideas among team members. This is somewhat contradictary. This could be due to the difficulty in mapping and understanding 'capability'. As Participant 2 pointed out, capability can be seen as "more than just… equipment displayed on a map" and that it also relates to "people, skills and training to deal with particular emergencies" (Dept of Communities & Local Govt).

Step 6: Monitoring and Reviewing

Monitoring and Reviewing involves a multi-agency team continuously monitoring risks and, if necessary, repeating the previous steps (1-5) when new risks are identified. The following statements were asked in order to evaluate the usefulness of the interactive map in Monitoring and Reviewing:

U69. The interactive map helps multi-agency teams to collaboratively update, review and maintain information regarding local risks.

U6a. The interactive map would help with the ongoing monitoring of risks.

Table 9. 10: Statistical summaries from the evaluation on the perceived effectiveness for Monitoring and Reviewing of an interactive map

	U69	U6a
Min	3	2
Median	4	4
Max	5	5
Mean	4	3.66

* Min – minimum, Max – maximum

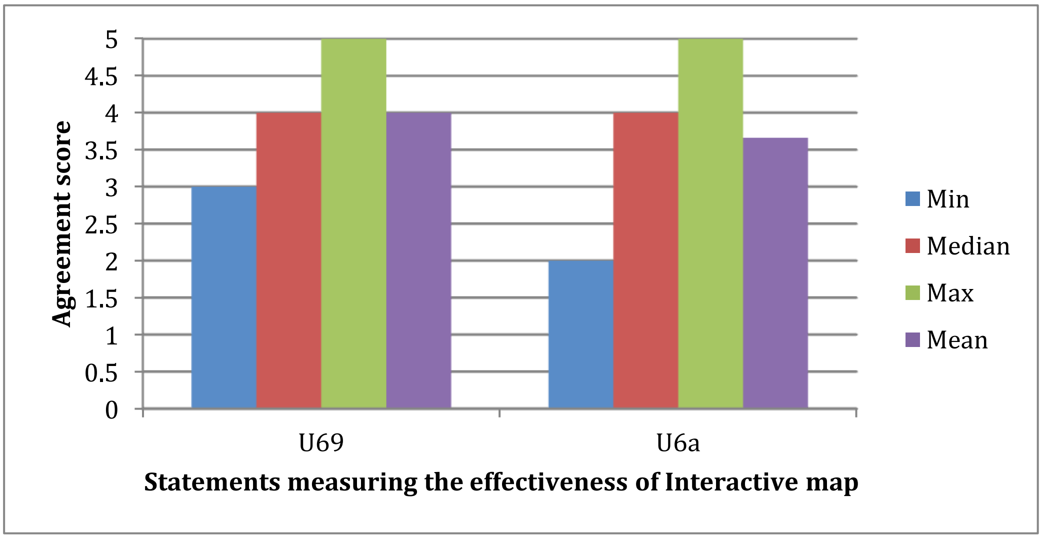


Figure 9. 10: Clustered columns showing the distribution from the evaluation on the effectiveness for Monitoring and Reviewing of an interactive map

Table 9. 10 and Figure 9. 10 show the statistical summaries of the participants' evaluation of the perceived effectiveness of the interactive map in monitoring and review. Both statements received median average scores of 4 and maximum scores of 5. However, the first statement, relating to the system's support for collaboratively updating, reviewing and maintaining risk information scored a slightly higher mean average score of 4, compared to 3.66 for the question relating to continuous monitoring. There was broad support among interviewees for the creation of an interactive map that would, by nature, act as a reference for future risks. A number of participants pointed out that careful, consistent updating of the map would be required in order to support monitoring and reviewing. Participants 16, 13, 12 and 5 all suggested that the system would be an overall success if it was maintained successfully.

9.3 Perceived effectiveness of the potential of the Interactive Map for strengthening the collaboration between multi-agenciess.

The second aspect (the "perceived effectiveness" of the potential of the interactive map for strengthening the collaboration between multi-agencies) covers how well the interactive map enhances the decision-making, communication and coordination of multiagency teams. This relates to a range of sub-skills, such as the extent to which the interactive map enhances group reasoning, interpretation and assessment skills. It evaluates the interactive map's enhancement of a team member's ability to express their views, ideas, information and agendas. It also evaluates how well the interactive map enhances the reasoning, assessment and interpretation skills of team members when they are faced with the complex situations they encounter in risk assessment. The following statements were asked to evaluate the usefulness of visualisation on the interactive map for a successful interactive and collaboration environment:

- Ua. The interactive map enhances the interaction between multi-agency teams in terms of decision making, communication and coordination.
- Ub. The interactive map helps teams to take turns in expressing their views.
- Uc. An interactive map system is helpful for multi-agency teams to build up a common understanding of the potential local risks.
- Ud. An interactive map system can improve the efficiency of communicating ideas and information.
- Ue. An interactive map system has real value as a tool where there is a need to communicate complex agendas to multi-agency teams.
- Uf. An interactive spatial map enhances the interpretation skills between multi-agency teams (such as breaking goals into sub-goals and questioning deeply).
- Ug. An interactive map enhances the reasoning skills between multi-agency teams in terms of a user's ability to think logically, justify priority levels, etc.
- Uh. An interactive map enhances the assessment skills between multi-agency teams in terms of a user's ability to rationally weight options.
- Ui. An interactive map enhances the meta-cognitive skills between multi-agency teams in terms of producing multiple ideas and dealing with the incident that has happened when making decisions.
- Uj. An interactive map enables users in multi-agency teams to look beyond the first obvious explanations to consider alternative interpretations.

Uk. An interactive map enables users in multi-agency teams to use mental imagery to evaluate plans.

Table 9. 11: Statistical summaries from the evaluation on the effectiveness of the interactive map for successful, interactive and collaborative multi-agency decision making.

	Ua	Ub	Uc	Ud	Ue	Uf	Ug	Uh	Ui	Uj	Uk
Min	2	1	2	2	1	1	1	1	1	1	1
Median	3	2	4	3	4	3	3	3	2	4	4
Max	4	4	5	5	5	4	4	4	4	5	5
Mean	3.52	3	3.95	3.69	3.69	3.13	3.21	3.34	3.13	3.3	3.78

* Min – minimum, Max – maximum

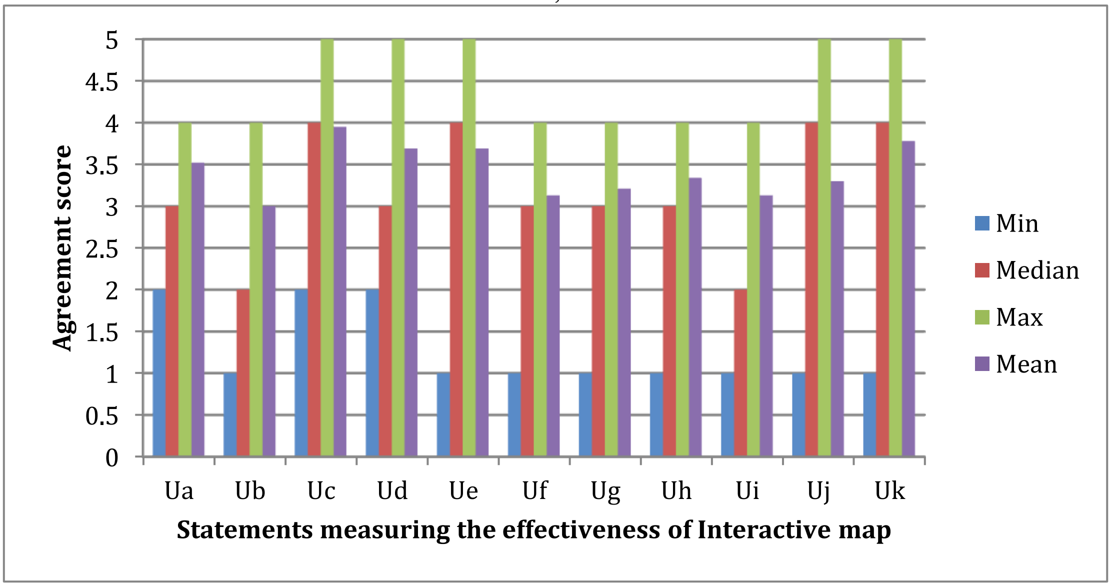


Figure 9. 11: Clustered columns showing the distribution on the evaluated effectiveness of the interactive map for successful, interactive and collaborative multi-agency decision making.

Table 9. 11 and Figure 9. 11 show the statistical summaries of the participants' evaluation of the perceived effectiveness of the interactive map in enhancing interaction and collaboration. The statements produced a consistent level of satisfaction with little variation between the statements. The mean average score for each statement was good, with all statements scoring 3 or above. The highest rated statement was Uc, which received an average of 3.95. The relates to the interactive map system's helpfulness for multi-agency teams in building up a common understanding of the potential local risks. Similarly high scoring statements were Uk, Ud and Ue. This means that the interactive map was rated well for its ability to help team members to communicate ideas, information and complex agendas and to help team members use mental imagery to evaluate plans. The interactive map's effectiveness in prompting debate and discussion between team members was commented on by Participant 16 who suggested that it

“provoked thinking” and “debate” (Association of Greater Manchester Authorities). Participant 13 was also positive about the system’s usefulness in reasoning, suggesting that it enabled “immediate reasoning” and “justification” of views and opinions (The Environment Agency).

On the other hand, the interactive map received lower average satisfaction scores for statements Ub, Uf and Ui, which relate to its ability to help team members express their views, to support the interpretational skills between multi-agency teams (such as breaking goals into sub-goals and questioning deeply) and to enhance meta-cognitive skills between multi-agency teams (such as producing multiple ideas and dealing with the incident that has happened). Participant 3 suggested that there was a danger that the map could impede decision making by providing “too much information of too low a level, such that it may overwhelm decision makers” (Ministry of Defence). Participant 13 also suggested that the usefulness of the system in helping decision making would “depend on the range of data available” (The Environment Agency). Moreover, Participant 6 suggested that, at this stage of its development, the interactive map is “too hypothetical” for its usefulness and effectiveness in collaboration to be judged (Association of Greater Manchester Authorities). These comments suggested that the information provided by the system has to be carefully selected if it is to help collaboration between decision makers. However, it is notable that all of the statements still received a good level of average satisfaction for each statement.

9.4 Summary

This chapter described the evaluation of the interactive map for use in multi-agency collaboration during the risk assessment process. The method of evaluation and the flood scenario were described before the setting for the evaluation and its procedure were outlined. Finally, the results of the evaluation were presented.

The results were analysed according to two different aspects. Firstly, perceived effectiveness of the potential of the interactive map in supporting risk assessment processes was analysed. This covered all parts of the risk assessment process including contextualization activities (related to understanding social, natural, infrastructural and hazard site risks in an area) hazard review activities (related to the identification of significant risks), risk analysis activities (related to assessing risk outcome and impact), risk evaluation activities (related to the identification and prioritisation of local risk hotspots) and risk treatment activities (related to the identification of a multi-agency team's existing capabilities and the identification of gaps in them) and monitoring and reviewing (relating to a multi-agency team reviewing risks in the future and repeating the previous steps when new risks emerge).

Secondly, perceived effectiveness of the potential of the interactive map for strengthening the collaboration between multi-agencies was analysed. This aspect related to the interactive map's enhancement of decision making, communication and coordination within multi-agency teams. This relates to a range of sub-skills, such as group reasoning, interpretation and assessment skills, and each team member's ability to express their views, ideas, information and agendas when faced with the complex situations they encounter in risk assessment.

The overall results of the evaluation were positive and indicated a generally good level of satisfaction with the interactive map. This finding suggests that the interactive map platform is generally helpful both for the specific activities relating to risk assessment and for promoting collaboration in a multi-agency environment. The overall result suggests that professionals view the interactive map as having the potential to support multi-agency teams in the planning and response phases of the disaster management cycle, but this finding will be discussed in greater depth and detail in the following chapter. The evaluation results were broadly positive with the participants, in general, being supportive of the interactive map prototype and positive about its use in supporting multi-agency collaboration and in enhancing the risk assessment process. The next chapter presents a discussion on the findings from the primary and secondary data and the limitations of this study.

Chapter 10 – Discussion

10.1 Introduction

The following chapter combines the insights gained from all of the previous parts of this research, bringing together and discussing the findings from the primary and secondary data. It also presents the limitations of this study and suggests areas of future research. Firstly, however, it is useful to summarize the project as a whole.

The purpose of this research was to identify the functional characteristics of an interactive map that can enhance multi-agency team collaboration in the risk assessment process in disaster management. The requirements for this interactive platform were gathered by working closely with the Greater Manchester Local Resilience Forum. Interviews were conducted with senior managers from various agencies involved in Category 1 responders in the Greater Manchester Local Resilience Forum (LRF). They represented strategic and tactical levels within the police service, fire and rescue service, ambulance service, National Health Service, local authority, the Environment Agency and Transport for Greater Manchester. The interviews were recorded and transcribed in order to define the characteristics of a collaborative environment for risk assessment in disaster management. These characteristics were used to define user requirements for an interactive map system which was then developed according to these requirements. The interactive map prototype was then presented to the members of the Greater Manchester Resilience Forum Development Group. This group included Category 1 & 2 responders. Category 1 responders comprised professionals from such agencies as the Department of Communities and Local Government, GM Fire and Rescue Service, the Association of Greater Manchester Authorities, GM Police, British Transport Police, the North West Ambulance Service, the Environment Agency, the NHS, Public Health England. Meanwhile, category 2 participants included representatives from The Highways Agency, Transport for Greater Manchester, BT and the Radio Amateur's Emergency Network, United Utilities, the Ministry of Defence and from the University of Manchester. Participants from these organisations were presented with a scenario that demonstrated the prototype. They then participated in a group discussion in which they discussed their views on the prototype's potential usefulness. This discussion was followed by the distribution of a paper questionnaire which included both open and closed questions and ratings' scale questions. The questionnaire was used as a method of capturing the individual views of participants. The findings collected from these questionnaires were presented in the previous chapter.

10.2 Contextualization of Social Information

The findings of this research were consistent with those of Peterson (1995) who suggested that interactive maps are a useful means of highlighting information in a visual form and, therefore, are easy to comprehend. The results of this study showed that the visual aspect of the interactive map was important for participants. The map was described as being useful for identifying affected populations visually and was identified as a good, useful visual tool. Awal (2003) suggested that providing overlays to visually identify areas of a community at risk from flooding was useful. This was supported by this research's findings, in which the layering of social information was identified as being useful. The findings point to a lack of agreement on the question of which social information should be included, with participants differing on their preferences. The findings point to the need for simple social information (such as population density, ethnicity, vulnerable people, schools' and hospitals' data) to be displayed as percentages.

On the other hand, the findings also point to a desire for the interactive map to include more complex factors such as the level of social media and Internet use in order to help the authorities decide the best way to communicate with the public. Communication and cooperation with the public emerged here as being important in evacuation situations, not only as a matter of language but also because there is distrust of authorities within certain communities.

In terms of social information, the author takes the view that the interactive map should provide relatively simple social information. Aspects of social information such as population density, ethnicity, vulnerable people, schools' and hospitals' data are undoubtedly useful for multi-agency decision makers. This kind of data could be displayed as a percentage, rather than as raw numbers, so as to simplify the data for decision makers. Moreover, the combination of such data sets into hot spots is useful for multi-agency decision makers. Given the increasing use and importance of social media and the Internet in modern, developed cities, the author suggests that giving multi-agency teams access to information relating to the level of internet use, and to social network use by the public would also be useful. This kind of data would be reasonably easy to access and visualise as a layer on the interactive map. However, the suggestions of some participants that the interactive map could include information about tensions between members of a community and the authorities, while being well-intentioned, are largely impractical. By its nature, this kind of information would be difficult to accurately collect and it also risks overwhelming users with overly complicated and difficult to use data.

10.3 Contextualization of Local Infrastructure

Understanding the information relating to infrastructure emerged as being extremely useful for the interactive map to display, which reflects the findings of past research (GISCaf, 2011, AAM Modelling Aids Brisbane Flood Crisis). Participants rated the interactive map's provision of information relating to infrastructure as highly useful, reliable and easy to access. The following elements of the infrastructure were identified in the findings as being important and well visualised on the map: water distribution points, electrical substation locations, health facilities and telecom substation locations. These elements emerged as being more important for multi-agency decision makers than other aspects of infrastructure such as financial institutions and heritage sites. However, the findings indicate that the usefulness of the interactive map would be increased with a greater emphasis on cascading effects on infrastructure, such as the effect a flood would have on an electrical substation and what effect the substation's failure would have on, for example, a local hospital.

Here, the author feels that the interactive map prototype's visualisation should include critical infrastructure that would have the biggest impact if affected, such as electricity, gas and telecommunication substations, water distribution points and health facility locations. It should also definitely include major roads because these are vital in dealing with disasters when they happen. The location of residential buildings like houses, flats and bungalows are also important because they may need to be evacuated. The locations of police, fire and ambulance stations are also vital, given that knowing the location and the level of current response capability is a key aspect of the risk assessment process. As for cascading effects, these can be visualised but only to a certain extent. The map allows users to visualise the number of houses that would lose electricity if a substation were lost, but to visualize a long list of possible knock-on effects would requires a simulation model that can handle complex cascading effects. This could be considered as potential future research work.

10.4 Contextualization of the Natural Environment

The interactive map's visualization of the natural environment reflected previous work by a number of writers (Gold and Condal, 1995; Goralski and Gold, 2007b) who suggested that 3D visualisations are helpful for assessing environmental impact, landscape planning and geology. The interactive map's provision of this data was broadly rated as favourable, and it was argued that particular attention should be given to sites of special scientific interest (SSIs). As with social information, the choices relating to which data to include on the map again emerged as being critical.

In this area, the author feels that the information provided by the interactive map should be prioritised according to its relevance to the protection of the public and property. The most obvious examples of natural environmental information in the map include the locations of reservoirs and rivers. Natural information could also include, for example, forests that could catch fire, or zoos and the types of animals they house. The author takes the view that including information about the location of SSIs, rare plants and animals on an interactive map would be useful in order to protect them. This information would, however, need to be managed carefully in order to avoid overloading decision makers with information that might not be of great importance to them in an emergency situation that threatens human life.

10.5 Contextualization of Hazardous Sites

The findings of this research are consistent with Dransch et al. (2005) and the Institute for Ocean Management (2007) who studied the use of interactive maps for mapping hazards for the visualisation of risk information and for communicating this information among team members. In this research it was reported that an interactive map system could inform current planning for hazards and the creation of support maps. Also a participant suggested that the system would support decision makers "in terms of…COMAH" sites. Experts in the field noted that the interactive map would be particularly useful in understanding the threat posed by COMAH sites, especially in mapping the effect that changes in wind direction could have on the surrounding areas if a COMAH site suffered a fire and emitted chemical smoke.

The author views the locational information and detailed information about the nature of hazardous sites as being vital to an interactive map system because these sites pose significant risks and need to be approached in different ways and with different equipment depending on the type of site. For instance, COMAH sites such as chemical storage facilities, chemical production factories and oil rich sites could affect their surrounding areas with plumes of dangerous smoke if they had a fire. Such sites pose different risks to those posed by university laboratories which may contain a range of biological, biometric and radiological risks for the surrounding area. Given the diverse nature of these threats it is, therefore, crucial that this hazard site information be available to decision makers in the context of an interactive map.

10.6 Hazard Review

The interactive map's ability to act as a communicative tool in hazard review activities emerged from this research's findings, supporting the views of Kolbe (2005), Marincioni (2007), Kemec et al (2010), and Zlatanova et al. (2002) who all noted the potential of interactive maps for this purpose. However, the findings in this study suggest that, in hazard review activities, the interactive map is more effective for visualising past data (such as previous floods) than it is for visualising less concrete information such as stakeholders' experience, intelligence and research data. This suggests that although stakeholders feel that having access to data relating to experience, intelligence and research is desirable, it may be difficult to visualise this data in a useful way in practice.

10.7 Risk Analysis

Literature on interactive mapping suggests that 3D models are useful in identifying features such as the locations of vulnerable people? Buildings in a potential flood plain, commercial buildings, roads and natural features like rivers and green spaces (Alexander, 1993; Shaluf, 2007). Demirel (2004) also suggested that interactive map models were useful in understanding, and planning for, transportation. The findings from this study are consistent with these aspects distilled from past research, with the interactive map emerging as being useful in visualising the potential impacts of a disaster such as flooding on critical infrastructure, utility services, parts of the natural environment (like wildlife and plant life) and the number of buildings affected. Understanding and analysing potential risks to transport networks also emerged as another strength of the map, in line with the study of Demirel (2004). Moreover, the interactive map has been found to be useful in helping multi-agency teams gain a collective understanding of the impact of hazards on people in the area. Therefore, the layers of information provided by the interactive map have emerged as being useful in highlighting these specific areas that could be impacted upon by hazardous events. However, the experts felt that the interactive map's ability to help users visualise economic impacts is less strong. Similarly, experts commented that the visualisation of information such as experience and tacit knowledge is difficult to represent in on interactive map. Moreover, in contrast to the discussion on the contextualisation of local infrastructure, in a discussion on risk analysis the interactive map was found to be useful in depicting cascading effects. This suggests that the interactive map is useful in visualising some types of cascading effects, but perhaps not all. On the other hand, it could suggest that the map's visualisation of cascading effects is more useful at certain stages of the risk assessment process, such as risk analysis, and not as useful at other stages, like contextualisation.

10.8 Risk Evaluation

The literature suggests that it is in the risk evaluation stage that the values and judgments of stakeholders start to have a large influence on the risk assessment process (UN-ISDR, 2004). The findings of this research suggest that the interactive map supports stakeholders in expressing their opinions and in justifying their judgments, because it makes immediate reasoning and justification possible. Moreover, risk evaluation involves considering the social, environmental, and economic consequences of estimated risks (UN-ISDR, 2004). The findings of this research suggest that an interactive map supports risk evaluation by bringing all of this information together in a single platform. The key elements of this study's findings indicate that layered information visually enhances the evaluation of risk hotspots. However, the experts felt that the right level of detail and range of this data is open for further debate.

10.9 Risk Treatment

The literature suggests that the most important aspect of an interactive map is how it can provide an accurate, up-to-date and comprehensive list of resources (MO-FEAT, 2008; CDC, 2015). Moreover, the literature relating to interactive maps suggests that they are useful in showing the location of available resources visually and that it is useful for the map to easily search for relevant resources (MO-FEAT, 2008; CDC, 2015). All of these aspects are key in the risk treatment stage of the risk assessment process. The findings from this study partially support the findings from the literature, because the interactive map was found to be helpful in understanding current capabilities and gaps in an area and in identifying the number of specfic resources available. Moreoever, the map was found to promote collaboration in these activities, namely identifying available resources. However, this study also found that the interactive map was less useful in helping users to understand overall capability and to keep track of resources. This contradiction in the findings is arguably due to differences in how the term 'capability' is understood by stakeholders. Levels of resources, such as fire engines, ambulances and related equipment, are relatively easy to monitor and then visualise on a map. Numbers of emergency personnel are also relatively easy to keep track of. However, this study found that the understanding of capability involves more than just resources and also includes elements like the training the staff have had and their skills and experience. This is much harder to visualise on a map. Perhaps some stakeholders understand 'capability' in terms of physical resources and equipment, while others understand it in its broader sense. This could explain the apparent contradiction in the findings and the difference between the findings of this study and those presented in the literature.

10.10 Monitoring and Reviewing

The cyclical nature of the risk assessment process suggests the importance of constant monitoring and reviewing. Wisner et al. (2004) stated that stakeholders need to monitor risks in order to know whether their risk treatment activities have been successful. If risks persist then it is logical that they continue to be assessed. They suggested that stakeholders must investigate any changes to local risk, such as the emergence of new risks or changes in likelihood of a risk or a potential impact of a risk. The Australian guidelines place a similar importance on monitoring and reviewing and suggest that stakeholders periodically reassess all risks in-depth (Standards Australia/Standards New Zealand Standard Committee, AS/NZS ISO 31000:2009). The findings of this research clearly indicate that, in order to be successful, an interactive map platform needs to enable users to update and maintain it in a systematic, thorough way. Moreover, such findings consistent with Alexander et al. (2011) who stated that keeping up-to-date information is a challenge, particularly when social data is usually collected periodically (using censuses for example) while hazards, on the other hand, can be dynamic and constantly changing.

10.11 Interactive Map for Successful Interactive and Collaborative Multi-agency Decision Making

Andrienko and Andrienko (1999) described maps as important tools in decision making, while Gold (1993) argued that interaction and communication should be kept as simple and as quick as possible in order to support decision makers. The usefulness of interactive maps as communication tools (in turn, supporting decision-making) has been suggested by numerous writers such Kolbe (2005), Marincioni (2007), Kemec et al (2010) and Zlatanova et al. (2002). On the one hand, the findings from this study can be seen to support the literature because it has found that the interactive map promotes debate and discussion and enables users to reason quickly and to justify their opinions. On the other hand, the level of information provided by the system and the effect that this has on decision making was controversial. It was suggested that too much information, or information of the wrong kind, could act to slow down decision-making.

The findings of this study support the conclusions of Ramsey (2009), Couclelis and Monmonier, (1995) and Elwood (2006) that interactive maps enable users to perform tasks intuitively and efficiently because they allow users to visualize the outcomes of their decisions during the decision making process. This study found visualisation and communication to be key strengths of the interactive map. That said, again the level and nature of the information being visualised was found to be important, with stakeholders disagreeing on the level of information they feel they require.

The literature points to the role of interactive maps in bringing together the complex agendas of numerous different organizations such as members of the local population, local government, non-governmental organizations and responders (Institute for Ocean Management, 2007). This is supported by the findings from this study which found that stakeholders felt that the interactive map was useful for this purpose.

One of this study’s main interests has been to understand how an interactive map could support the critical thinking of its users and the overall findings support the map’s use for this purpose. Critical thinking can be broken down into a range of sub-skills. However, the existing literature relating to interactive maps tends to focus on one of these sub-skills, mamely, reasoning skills. Writers such as Kraak (2006), Petrovic and Masera (2005), Andrienko et al. (2001) and Guo (2003) have found that interactive maps promote reasoning by enhancing a user’s spatial reasoning abilities while Adrienko and Adrienko

(1999) suggested that an interactive map can help users in finding information that may otherwise be overlooked when exploring data. The interactive map in this study was found to be useful in promoting visual thinking and efficient, quick reasoning among users. More generally, the interactive map was found to promote and provoke thinking by users. These findings are, therefore, consistent with the literature. However, this study also found that the interactive map could support a range of other, additional, critical thinking skills such as meta cognitive strategies (in which individuals reflect on their thinking strategies and assess them) because the map promoted the production of multiple possible ideas, deep questioning and the breaking down of goals into sub goals. In addition, visual thinking, producing alternative explanations, and planning and weighing ideas rationally, were all also found to be enhanced by the use of the interactive map.

10.12 Importance of Interactive Maps for Risk Assessment

This research has been based on the general premise, as suggested by Alphen et al. (2009), that interactive mapping is a “keystone” of risk assessment. The general support for the interactive map system that was developed for this study is consistent with this claim. The support for the interactive map system found among the stakeholders in this study supports the findings of Shen and Kawakami (2010) that such maps can improve the understanding of risk and can improve communication among planners and experts. In addition to asserting that interactive mapping helps planners and stakeholders, Shen and Kawakami (2010) found that such maps could enhance the understanding of members of the public. While this was not an aspect of this study, the findings do indicate that an interactive map can be used to guide stakeholders in how they can communicate with the public. For instance, it was suggested that, in the area of social information, the map could provide information about language use, internet access and social media use that stakeholders and planners could use to plan their communications with the public in times of emergency. This finding is consistent with the findings of past research (Marcus 2001; Shen et al. 2006; Edsall 2007) which suggested the need to investigate differences in the social conventions and interactions in diverse communities in order to communicate effectively with the members of those communities. Moreover, the findings suggest that information could be provided on the map in relation to the communities which are hard to reach, perhaps because of tensions and a lack of trust by those communities of the responders. More generally, the findings of this study suggest that the interactive map is, indeed, helpful for risk assessment and that topographical information, impact assessment and critical services mapped on a system like this serves to help in risk assessment.

10.13 Importance of Data: Choices, Visualisation, Security and Updating

A reoccurring theme in the findings is the importance of the data in supporting a useful interactive map system. As such, the findings support the submission of Kemec et al. (2010), that interactive mapping is based on the capture, sampling and structuring of data. The literature suggests that the data utilised depends upon the approach taken by the systems, which can be a communicative approach or a visualisation approach. Maceachren and Gaunter (1990) suggested that a communicative approach demands that an interactive map should accurately represent and display the reality of an area, while the visualisation approach demands that a map be able to predict and simulate hypothetical situations. Some parts of the findings of this study suggest that the interactive map was useful primarily as a communicative map, displaying the reality of a given situation, but was not as useful as a predictive tool. However, there was some discussion among the participants about the nature of simulation and prediction, with some participants suggesting that the prediction algorithm built into the map could be useful during disaster when one needs to work with real-time data. The example given was that of rainfall. The interactive map shows the effects of different levels of rainfall on a given area. In doing so, it simulates a hypothetical event using historical data. The interactive map allows users to ask 'what would happen if the river increased by 1 metre?' This is different to a map that allows users to ask 'what is going to happen to the river in 1 hour". In order to predict and not only simulate, the map would require real- time data about, for example, the level of the river and the current rainfall situation. The map would then need to predict the outcome of a continuation of this level of rain using a simulation environment. Such a map could be useful for the responding stage of the disaster management cycle. However, this research has focussed on the assessment and preparation stage in the context of Integrated Emergency Management. In short, the map created can simulate events, but not predict them in the way that some users may want.

The distinction between prediction and simulation raises another issue that is central to this research and that is the nature of the data provided by the map. In order to predict in the way that some users would like, the map would require real-time data and simulation support. However, even without real-time data, the type of data to be included on the interactive map was a source of discussion and of different views between the stakeholders. There is some contradiction in the findings, with a central theme being that too much information can overwhelm decision-makers. The findings suggest that some users find the interactive map to be too congested and that the data should be simplified to contain less personal data. On the other hand, some participants called for the inclusion of more data, such as level of Internet and social media use by members of a community. This study found that keeping the data provided up-to-date was important for the stakeholders. It was suggested by some stakeholders that the interactive map was too ambitious to maintain. This was felt particularly in relation to the social data which can change quickly. It is clear from the findings that, in order for an interactive map to be successful, then a detailed plan to gather, manage, secure and update the data would be required. Moreover, the legal aspects of data protection would need to be fully explored in order to reassure stakeholders that all data protection and confidentiality regulations were met. While the interactive map used in this research was designed according to the characteristics captured from stakeholders, there would have to be continuing discussion about the type of data that should be maintained in such a map. This could be the result of different stakeholders having different priorities depending on their needs and responsibilities.

Another issue relating to the data is the best way to visualise it. Visualisation is a key aspect of mapping and the findings of this study reflect statements made by Andrienko and Andrienko (1999) and DiBiase et al. (1992) that interactive maps are crucial to the promotion of visual thinking. This study's findings endorse this view, with the promotion of visual thinking emerging as a key strength of the system. This is important in light of suggestions made by McCarthy et al. (2007) that effective visualisation is a factor in encouraging users to make decisions and solve problems in a flexible way. Another element specified by McCarthy et al. (2007) is an effective user interface. This factor was supported by this study, in which the interactive map was found to be easy to use and interpret. The use of heat mapping and icons to visualise the population density of vulnerable populations emerged as a benefit. Moreover, the ability of the interactive map to provide layers of information emerged as an advantage, enabling users to switch between individual data sets and the overall, bigger picture of the local risks of an area.

Aside from visualisation, the use of interactive maps to enhance collaboration within multi-agency teams is another core aspect of this research. As noted by writers like O'Brien (2000), Montague (2004) and Plapp (2001), collaboration is at the centre of the risk assessment process, with stakeholders working together throughout. Collaboration depends on communication and this study partially agrees with numerous previous findings that interactive mapping is useful as an effective means of communication (Kolbe, 2005; Marincioni, 2007; Raper, 1989; Zlatanova et al., 2002a). In general, the findings from this study suggest that the interactive map has the potential to support collaboration. The system provided a visual stimulus that provoked discussion and debate among users, which is central to collaboration. The findings also suggest that the system provides opportunities to immediately justify views and opinions, which is central to collaboration. Moreover, it emerged that, in theory, the system could help multi-agency teams reach a collective understanding of risks. However, the system would need to be further tested, with teams of users given the opportunity to actually use the system in collaborative exercises, to truly test the system's usefulness in this regard. Hypothetically, the system supports collaboration, but further research is needed to investigate this in practice.

10.14 Use of an Interactive Map Before and After Disaster

This research has operated within the context of Integrated Emergency Management which consists of six kinds of closely related, and sometimes overlapping, activities. These are anticipation, assessment, prevention, preparation, response, and recovery management. This study has focused on the use of interactive maps in risk assessment activities and preparation activities. Dransch et al. (2005) suggested that interactive maps enhance the assessment, analysis and mitigation of risks, while Van Westen (2013) suggested that interactive maps are required in mitigation activities. However, there is some disagreement between writers over the use of interactive maps in the stages of emergency management. For example, Anwal (2003) suggested that interactive maps can be used in activities before an event (the assessment, prevention and preparation activities) and also in recovery activities after an event. The findings from this research contribute to this debate. The interactive map is commonly cited in the findings as being useful in planning activities. Therefore, in the Integrated Emergency Management model, the interactive map is useful in the pre-event stages and is consistent with the views of Dransch et al. (2005). The findings indicate the system's usefulness at both a tactical and strategic level. However, the findings also indicate the interactive map's usefulness in response activities, which was widely cited in the feedback. This finding is open to interpretation because 'response' is closely linked to planning; when stakeholders plan, they plan what response they would initiate in the event of a certain occurrence. The feedback may simply indicate that the interactive map enhances planning which involves thinking proactively about responses. On the other hand, the feedback could suggest that the interactive map could be used in real time as a response is being carried out in reaction to an event. This is questionable, however, given the lack of real-time, live data in the system that has been previously described. One way to overcome this is to simulate such real-time data and provide an incident as if it is a real incident. This will allows agencies to use the interactive map as a training tool in the future and be prepared to respond to incidents.

10.15 Evaluation of the Research Approach and the Validity of Data Collection in Relation to the Aim of the Research

The aim of the research is investigate the nature of an interactive map that can enhance multi-agency team collaboration in the risk assessment process in disaster management.

The research philosophy adopted in this study is interpretivist and the research approach is inductive. The question to be answered here is how the research approach and philosophy support the achievement of the aim of the present research. The philosophy adopted in the current research is interpretivism. This philosophy is based on the assumption that reality is not objective; it is rather constructed by people who give it its meaning. The perspectives and the beliefs of the participants in an interpretive study are important in shaping and forming reality in the study. Other features of interpretive research are qualitative data collection and analysis methods, small samples and an in-depth understanding of the phenomenon under investigation.

The other issue that intensifies the interpretivist nature of the current study is the adoption of the activity theory. The activity theory is a framework for the analysis and understanding of human interaction through the use of tools or artefacts. It is based on deriving qualitative data from participants in an interpretivist way. Additionally, the activity theory provides a general discovery method that can be used to support qualitative and interpretative research. Thus, the use of the activity theory lies at the heart of interpretive research that uses qualitative methods.

The approach used in this research is inductive which is consistent with the adoption of the interpretivist philosophy. The research aims at investigating the nature of an interactive map that can enhance multi-agency team collaboration in the risk assessment process in disaster management. The investigation started based on a cohort of assumptions and objectives regarding the development of an interactive map.

The interviews conducted in the current study with senior managers from Category 1 responders in The Greater Manchester Local Resilience Forum yielded user requirements. These requirements can be categorised in order to define a set of characteristics for the collaborative environment for risk assessment in disaster management. Data collected from the interviews show that the information required by the interviewees can be categorized under four main themes: Social (information relating to the human population of an area and its vulnerabilities), Natural (information relating to the natural environment of an area and its vulnerabilities), Critical infrastructure (information about the location and nature of key transport, communication and utilities in an area) and Hazard sites (information relating to the location and nature of sites in an area that present a hazard). These themes need to be plotted on a map and visualised by the stakeholders.

Therefore, the philosophy and the approach adopted supported the study in achieving its aim to investigate the characteristics of an interactive map that can be used in disaster management. These characteristics were derived from the data collected from interviews. The perspectives and beliefs of the participants played a crucial role in identifying the characteristics of the interactive map. Data collected qualitatively mainly contributed to shaping the interactive map and assessing how they could enhance collaboration between multi-agencies in disaster management.

10.16 Evaluation in Relation to the Use and Relevance of the theories and Models Used

The method of evaluation in this study was undertaken by asking the participants questions about the effectiveness of potential of the interactive map and its effectiveness from the participants' perspectives.

The main question is whether the evaluation method of the experiment has adopted the three models that have been summarised. The first model of the activity theory is used with its use of artefacts to stimulate the users' understanding and analysis through the use of artefacts.

The first evaluation (aspect) will measure perceived effectiveness of the potential of the interactive map in supporting risk assessment processes. This is undertaken by assessing the map's effectiveness in the activities carried out by multi-agency teams at each step of the risk assessment process. The second evaluation (aspect) is perceived effectiveness of the potential of the interactive map for strengthening the collaboration between multi-agencies. The assessment criteria relate to the effectiveness of the interactive map prototype in supporting risk assessment process activities and the interaction and collaboration of multi-agency decision makers. The following are the two aspects that were tested during the evaluation of the potential of the interactive map:

- Perceived effectiveness in supporting the risk assessment process (first aspect)
- Perceived effectiveness for strengthening the collaboration between multi-agencies (second aspect)

Features of critical thinking can be found in the two aspects and in the assessment criteria. For example, in the evaluation method, tasks and goals are divided in sub-sections. The questions on assessment are also based on the ability to understand and retrieve the gist of the material presented. The questions and the assessment criteria require the participants to question the subject matter deeply and to identify and challenge previously held assumptions. The criteria are also based on the ability to think logically, to apply general principles to specific cases and to determine if the evidence available is enough to justify the conclusions. The participants, when asked the assessment questions, must connect things logically and find evidence for the answers they provide. Overall, the assessment methodology used and the assessment criteria all require a type of critical thinking by the participants that enables them to connect different parts logically in order to make conclusions from the evidence and to challenge already existing assumptions and may be replace them with new ideas.

Team Collaborative Model: the questions and the assessment criteria address the participants collaboratively as a team wherein they are required first to discuss the subject with each other and exchange comments and perspectives, then they have modelled a plan of a constructed project and then they return to communicating with the designers to give feedback. The participants communicated with each other while using the interactive map with its different layers and the information it provided. They were introduced to different patterns of information which either reinforced their already existing assumptions or challenged them. They also evaluated how effective the interactive map was for them and their jobs and whether it provided enough information to be applied in the case of floods. All this activity required an ability to analyse, think and reflect as well as creating new ideas out of the available ideas.

10.17 Limitations

The main limitations of this study relate to the fact that it used a prototype interactive mapping system. The purpose of the experiment was to demonstrate the system itself and the categories of information included in it, rather than investigate the data within the system. As a result the situation presented to participants was based on both historical data and hypothetical data. This is a limitation of the research because some participants felt that this was too hypothetical. Others may have based their feedback on the potential usefulness of the system, rather than its actual usefulness in their local setting.

This is a specific limitation in the study's investigation into the interactive map's enhancement of collaboration. Participants were given an introduction and a demonstration of the system and were asked to discuss and give feedback on its likely effect on collaboration. However, they were not asked to actually use the interactive map in a collaborative scenario. Again, this means that participants' feedback about the collaborative aspect of the system was based on their thoughts about its potential, rather than in its actual ability to enhance collaboration. Another related limitation is that this study only gave participants one flood scenario. Showing participants multiple scenarios might have produced richer data and given them a greater understanding of the system.

Another aspect of this research relates as to how the initial consultation with the stakeholders was conducted. Stakeholders were interviewed to capture the characteristics that they required as part of an interactive map system. These interviews were held with small groups of stakeholders from the same agencies, with representatives of different agencies interviewed separately. Another approach, which could have produced different characteristics that may support multi-agency collaboration, would have been to conduct interviews with representatives from the multiple agencies together. Representatives could then have discussed the characteristics that they would like in a collaborative setting. This could have ensured that the characteristics that emerged would support multi-agency collaboration to a greater extent.

Finally, this study investigated the use of an interactive map in all parts of the risk assessment process. In doing so, it provides an overview of the map system's use, but does not provide findings that apply to each aspect of the process in-depth. Each stage of the process is complex, with numerous aspects and activities, and some of these aspects have not been considered in this study.

10.18 Summary

This study sought to develop an interactive map system that would enhance collaboration in multi-agency teams' risk assessment activities. The system was developed based on the characteristics identified by the stakeholders themselves in interviews and was then tested by demonstrating the system and then capturing feedback from a larger group of stakeholders. The feedback was analysed according to two different aspects: firstly, the perceived effectiveness and impact of visualisation on an interactive map in supporting risk assessment processes, and secondly, the perceived effectiveness of visualisation on an interactive map for strengthening the collaboration between multi-agencies.

There was broad satisfaction with the interactive map system. At the contextualisation stage of risk assessment, the map was found to be a good, useful tool identifying affected populations. Findings point to the need for simple social information (such as population density, ethnicity, vulnerable people, schools' and hospitals' data) to be displayed as percentages, while calls were also made for complex factors (such as the level of social media and Internet use in a community) to help with communication with the public. The map emerged as a useful tool for understanding information relating to local infrastructure, although it was found that a greater emphasis on cascading effects on infrastructure would improve the map. The map's contextualisation of information relating to the natural environment was also rated highly, but it was found that information relating to sites of special scientific interest should also be included. The map was found to aid the understanding of hazard sites, including COMAH sites.

In hazard review activities the map was found to be useful, although it was rated more highly for its visualisation of past data (such as historic floods) than for visualising more abstract information such as stakeholders' experience, intelligence and research data. In risk analysis activities, the map was found to be useful in visualising potential impacts on critical infrastructure, utility services, transport networks, parts of the natural environment (such as wildlife and plant life) and the number of buildings affected. At the risk evaluation stage, the interactive map was found to support stakeholders in expressing their opinions and in justifying their judgments, because it makes immediate reasoning and justification possible. In risk treatment activities the interactive map was found to be helpful in understanding the current capabilities and the gaps in an area, in identifying the number of specfic resources available and in supporting collaboration in this area. However, it was found that the map was weaker in helping users understand the less concrete aspects of 'capability' such as the skills and training of responders. At the monitoring and reviewing stage, the interactive map was found to be useful as way of bringing together comprehensive information but, at the same time, concerns were raised over the difficulty of maintaining the information from a variety of sources.

This research has found that the interactive map system promotes debate and discussion and enables users to reason quickly and to justify their opinions. The map was found to enable users to perform tasks efficiently. The map was found to promote visual thinking, efficient reasoning and communication among users. Moreover, the map was found to be useful in promoting meta-cognitive skills, use of mental imagery, producing alternative explanations and plans and weighing ideas rationally. On the other hand, the level of information provided by the system and the effect that this has on decision-making was controversial. It was suggested that too much information, or information of the wrong kind, hindered decision-making.

The findings of this study point to the important of interactive mapping in risk assessment, suggesting that topographical information, impact assessment and critical services mapped on a system like this serves to help in risk assessment. The research also suggests that interactive maps have the potential to help stakeholders decide how best to communicate with the public.

A reoccurring theme in the findings is the importance of data in supporting a useful interactive map system. The findings suggest that data security, maintaining and updating the data involved, and the legal issues surrounding data protection, present a challenge for the design and use of interactive maps. The study discovered that there was a desire by the participants for live, real-time data with the promotion of thinking enhanced by visualisation emerging as a key strength of the system. The use of heat mapping and icons to visualise the population density of vulnerable populations was found to be a strength, as was the ability of the interactive map to provide layers of information.

In general, findings in this study suggest that the interactive map has the potential to support collaboration. The system was found to provide a visual stimulus for discussion and debate, and a method for users to immediately justify views and opinions. There was broad support for the assertion that the interactive map helped teams to collectively understand risks.

The interactive map was commonly cited in the findings as being useful in planning activities. However, the findings also indicate the interactive map's potential usefulness in response activities, which was widely cited in the feedback. Given that planning activities often involve the creation of plans for certain responses, the finding of this study is that the interactive map is useful in proactive planning activities before an event. The next chapter presents the thesis' summary, the research contributions, and suggests areas for future research.

Chapter 11 – Conclusion

11.1 Introduction

This final chapter starts with the thesis' summary and is followed by an assessment of the research undertaken in order to understand its value and its success in addressing the research objectives. Then, the research contributions are introduced and areas for future research are suggested.

11.2 Thesis' Summary

The aim of this research is to investigate the nature of an interactive map that can enhance multi-agency team collaboration in the risk assessment process in disaster management. This research started with a review of subjects such as definitions of disaster, definitions of disaster management, guidance to the comprehensive approaches to disaster management, the risk assessment process, disaster preparedness, multi-agency collaboration, collaboration challenges, multi-agency collaboration practices in the United Kingdom, interactive maps, GIS and 3D visualisation. Also investigated and assessed were the theories and frameworks that are useful in understanding, analysing and supporting collaboration among multi-agencies in disaster management such as the cultural-historical theory (CHT) (Engeström, 2001), the critical thinking model (Fischer et al., 2009) and the team collaboration model (Patel et al, 2011). While a large amount of secondary data was evaluated, the research collected primary data to capture the characteristics that multi-agency stakeholders require from an interactive map that would enhance their activities in the risk assessment process.

This study sought to develop an interactive map system that would enhance collaboration in multi-agency teams' risk assessment activities. The system was developed based on the characteristics identified by the stakeholders themselves in interviews (for the characteristics see table 6.1). Then it was tested by demonstrating the system and capturing feedback from a larger group of stakeholders. The new additional characteristics that were put forward as a result of the evaluation data analysis were also found to be important in supporting multi-agencies in the risk assessment process. The new characteristics included a request that social information (such as population density, ethnicity, vulnerable people, schools' and hospitals' data) should be displayed as percentages, while calls were also made for more complex factors (such as the level of social media and Internet use in a community) to be shown to help with communication with the public.

Consequently, the interactive map's visualisation, and the manipulation through the different layers containing social information, and information on local infrastructure, natural environment and hazard sites, helped multi agencies to collectively understand the context of local risks. As an outcome, there was broad satisfaction with the interactive map system. The map was found to be a good tool for identifying affected populations, understanding information relating to local infrastructure and understanding the dangers/locations of hazard sites including COMAH sites. In addition, the map was found to be very supportive for hazards' review and risk analysis as well. It also supported the stakeholders in the expression of their opinions and in justifying their judgements at the risk evaluation stage. In addition, it was helpful in risk treatment activities. The map was found to promote visual thinking, efficient reasoning and communication among users. This research has found that the interactive map system promotes debate and discussion and enables users to reason quickly and to justify their opinions. Moreover, the map was found to be valuable in promoting meta-cognitive skills, in the use of mental imagery, in producing alternative explanations and plans and in weighing up ideas rationally.

The findings of this study point to the importance of interactive mapping in risk assessment, suggesting that topographical information, impact assessment and critical services mapped on a system like this serves to help in risk assessment. The research also suggests that interactive maps have the potential to help stakeholders decide how best to communicate with the public.

11.3 Research Assessment

In order to assess this PhD research, the following objectives, identified in Section 1.2, were examined to determine as to whether the research aim has been achieved.

Objective 1: To analyse the risk assessment process and capture key stakeholders' views on the risk assessment processes.

The objective was achieved in two ways. Firstly, the risk assessment process was analysed via an extensive literature review which contextualised risk assessment as one stage in the overall integrated emergency management context. The risk assessment process itself was broken down into activities. The first stage involves multi-agency teams contextualizing social, natural, infrastructure and hazard site risks in order to fully understand the local area. The second stage of the process is the Hazard Review, in which past experience, historical data, research or other information is used by multi-agency teams to collectively identify significant risks. The third stage is Risk Analysis, in which multi-agency teams seek to understand local risks in terms of their likelihood, outcome and impact. The fourth stage is Risk Evaluation, in which multi-agency teams work together to produce a risk matrix which identifies and prioritises local risk hotspots. The fifth stage is Risk Treatment, in which existing capabilities are identified and the gaps in these capabilities explored. The final stage of the process is Monitoring and Reviewing, in which multi-agency teams seek to collaboratively update, review and maintain information regarding local risks. The literature review identified these stages based on the standard widely recognized as being the best in current practice, used by developed countries around the world (Standards Australia/Standards New Zealand Standard Committee, AS/NZS ISO 31000:2009).

In this research, a Local Resilience Forum (LRF) in the UK was used as the main vehicle for capturing key stakeholders' views on risk assessment. One of LRF's key roles is to coordinate the risk assessment process in a local area. Therefore, LRF members were identified as key stakeholders in the risk assessment process and this research sought to capture their views. The collection of this primary data was conducted via interviews with representatives from the Category 1 responders that make up the Greater Manchester LRF. These subjects included senior managers from the fire and rescue service, the police, the ambulance service, the local authority, NHS England, the Environment Agency and the local transport authority. These subjects were asked for their views on the risk assessment process in semi-structured interviews. The outcome of their views was presented in chapters 3 & 6.

Objective 2: To identify the key functional characteristics of an interactive map that can enhance multi-agency teams' collaboration in the risk assessment process in disaster management.

This objective was, again, achieved in two ways. As the risk assessment process is based on collaboration, the relevant frameworks and theories relating to collaboration were analysed. This theoretical study helped to understand the nature of collaboration, the nature of tension and the skills of critical thinking that should be considered when developing a collaborative risk assessment environment. The characteristics required in such an interactive map were captured from interviews with stakeholders. The interviews were transcribed and analysed thematically to define the characteristics that stakeholders felt would enhance their multi-agency collaboration. The information required by interviewees emerged in four main themes: Social (S), Natural (N), Critical infrastructure (CI) and Hazard sites (HS). A detailed analysis of the information and the interaction features were presented in chapters 2 & 6.

Objective 3: To design the look and feel of an interactive map that can enhance multi-agency team collaboration in risk assessment processes in disaster management. This design specification will be used to implement a prototype of the interactive map with the support of a skilled IT person.

This objective has been achieved based on the requirements that emerged from the literature review and from interviews with stakeholders. Following the well-established and successful COA and TOGAF frameworks, the system's conceptual design integrates four views: Information view, Process/Activity view, User Interface view and Team Member view. This system aims to provide multi-agency team members with a variety of information from different sources.

Furthermore, the interactive map prototype presents the user with a map of an area. Using an interface, a user can place different layers of information over this map. The layers of information are: social information, natural information, infrastructure, hazardous site, resources and flood information. The system was designed using the Model-View-Controller architectural pattern (Krasner and Pope, 1988). The overall design of the interactive map was presented in chapter 7.

Objective 4: To evaluate whether the enhanced features of the interactive map has the potential to strengthen collaboration between multi-agency teams in risk assessment processes.

The objective above was achieved by an evaluation that involved 23 participants from the Greater Manchester Local Resilience Forum Development Group who attended an experiment in the Think pod, within Salford University's Think Lab. This evaluation was achieved by using the system to demonstrate layers of information relating to a flood scenario that was based on historical and hypothetical data. The layers of information demonstrated to the participants contained social information, natural information, infrastructure, hazardous site, resources and flood information. After viewing a demonstration of the system, participants were asked to discuss the platform and the scenario it presented as a group. The researcher observed this, enabling the capture of feedback. The questionnaires hand to the participants after the demonstration combined open, closed and rating scale questions to capture more specific qualitative and quantitative feedback from participants. The findings of the evaluation were analysed according to two aspects: firstly, the perceived effectiveness and impact of the visualisation on the interactive map on risk assessment processes and, secondly, the perceived effectiveness of the visualisation on the interactive map for a successful interactive and collaborative environment. The overall results of the evaluation were positive with both aspects receiving good levels of satisfaction from stakeholders. This finding suggests that the interactive map platform is generally useful both for the specific activities relating to risk assessment and for promoting collaboration in a multi-agency environment. The overall result suggests that the professionals view the interactive map as having the potential to support multi-agency teams in the planning and response phases of the disaster management cycle. The outcome of the evaluation was presented in chapters 8 and 9.

11.4 Research Contributions

This research contributes to the new knowledge on collaborative working within disaster management. It specifically focuses on enhancing knowledge by the application of interactive maps in supporting the six-step risk assessment process and multi-agency collaboration. This research has conducted an in-depth analysis to identify the key stakeholders involved in the risk assessment process as well as the information required to and analyse in order to create a common understanding of the local risks by conducting a thorough risk analysis. This knowledge has been extracted from secondary data as well as primary data through interview of the Category 1 responders. This in-depth knowledge has been used to establish a viable interactive map that can visually present the risks that is required in the six-step risk assessment process. The overall construction of the interactive map is also a contribution to knowledge due to its design using different system views such as Team Member view, Information view, Process/Activity view and Data Visualisation view.

Finally this research collected and analysed feedback from the Greater Manchester Local Resilience Forum development group to capture "perceived effectiveness" of such an interactive map in supporting the risk assessment process as well as its potential for strengthening the collaboration between multi-agencies. Specifically, this research has contributed to knowledge as follows.

- The identification of functional characteristics on interactive map this knowledge could be used by the researcher community to develop different type of interactive maps using other technology such as virtual reality (VR) to support collaborative risk assessment involving key agencies in a city.
- The research conducted in this research has lead to the implementation and demonstration of an interactive map. The implemented interactive map illustration has the data required for the risk assessment could be combined, visualized and manipulated to build up a holistic view of local risk and help multi-agency to engage in decision during various stage of the risk assessment process.
- Data an "perceived effectiveness" of an interactive map from category 1 responder in supporting the six-step risk assessment process as well as multi-agency collaboration. This contribution gives confidence to the research community that the outcome is not just hypothetical but has been valid by the practitioners who are engaged in risk assessment in a major city.

11.5 Future Research

Further work could be conducted to build on the foundation laid in this thesis to further enhance knowledge in disaster management:

- Testing in practice and getting objective results. Testing the use of the interactive map in real world risk assessment activities (or formal training exercises) involving a range of agencies and measuring the impact of the prototype on building resilience, enhancing preparation and supporting collaboration.
- Integrating various simulations to assess flood propagation, fire propagation and chemical cloud propagation will allow agencies to explore a range of possible scenarios and consider risk mitigation.
- Simulation of the cascading effect of a disaster event through disaster propagation models. The use of modelling technology, such as system dynamics and Bayesian belief functions, have been identified as possible approaches for modelling the cascading effects by an internal project within the Think Lab.

- Integrating the simulation of real-time events and data as a way of simulating hazards' events could allow the interactive map to be used for testing the preparedness of multi-agencies. This could become a powerful tool for training multi-agencies' staff in order to prepare them for responding to real events.
- This use of this environment during the event itself is a possibility. Future research could be conducted to understand how real-time data and resources could be integrated into the map to support real-time response and also how teams could interact with the map in real-time.

11.6 Summary

This research has resulted in the creation of an interactive map designed to enhance collaboration among multi-agency teams in risk assessment activities. It has combined primary and secondary data to produce a theoretical framework, a conceptual framework and a collaborative platform in the form of an interactive map. This interactive map has been found to have the potential to support multi-agency teams in the planning phases of the disaster management cycle.

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Appendix A

Appendix A Questions for semi-structured interviews to identify the characteristics of an interactive map environment

Questions for semi-structured interviews

Name:
Job title:
Company Name:
Experience in Emergency Management:

1. Background

Part 1 of the Civil Contingency Act 2004 establishes a consistent level of civil protection activity across UK. This Act provides a basic framework defining what tasks should be performed and how co-operation between Category 1 and 2 responders should be conducted. It aims to ensure greater consistency and co-operation at local level. The principal mechanism for multi-agency co-operation under the Act is the Local Resilience Forum (LRF), based on each police area.

Within the context of Integrated Emergency Management which defines six activities (anticipation, assessment, prevention, preparation, response and recovery management), the Act focuses on **risk assessment** and **preparation**. The purpose of the LRF is to ensure effective delivery of these two activities in a multi-agency environment.

The purpose of this research is to identify the characteristics of an interactive map environment (based on a spatial map) that can enhance multi-agency collaboration in **risk assessment**. This research uses the **six-step risk assessment process** proposed in the **Emergency Preparedness** report (Guidance on Part 1 of the Civil Contingency Act 2004) as the basis for structuring the questionnaire.

The key research question that we intend to investigate within this research exercise is: ***How can we enhance multi-agency risk assessment activities through an Interactive***

***Spatial Map that presents an integrated risk view of the local area**?*

2. Brief Introduction to the Six-step Risk Assessment Process

The six-step risk assessment process proposed in the Emergency Preparedness report is based on the standard used in Australia and New Zealand, which is widely recognized as being good practice. Figure 1 below illustrates the six-steps. A brief description of each of these stages is presented in Section 3 before presenting the questionnaire.

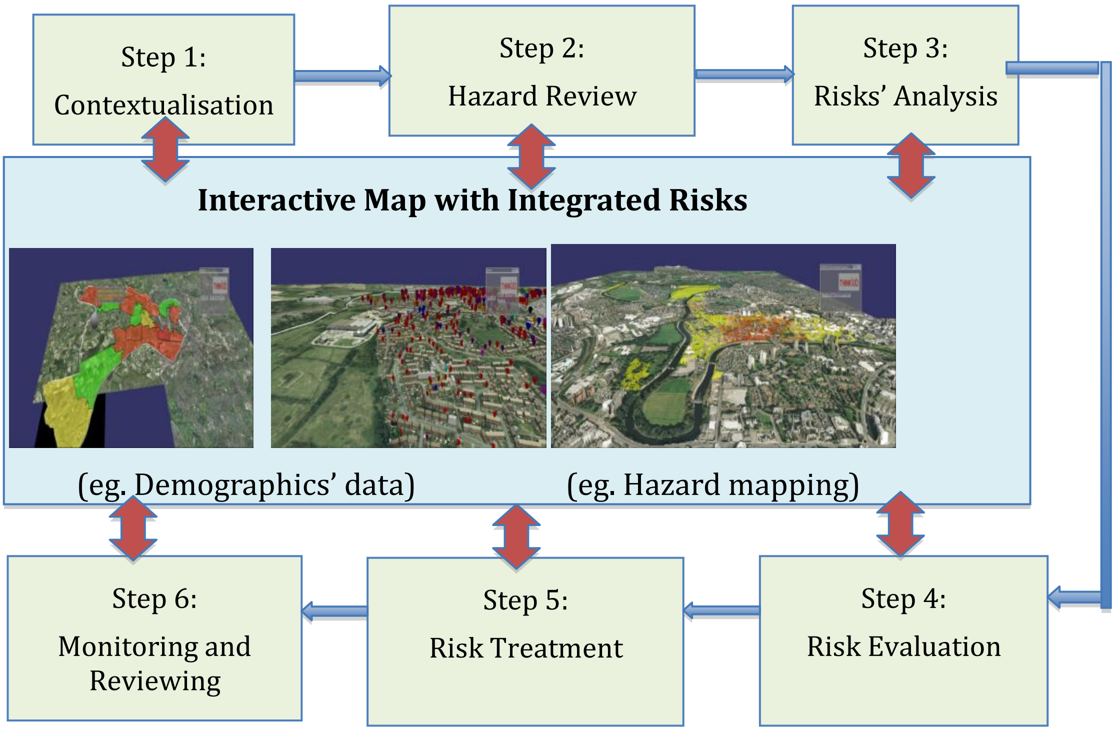


Figure 1: The Six-step Risk Assessment Process

3. Questionnaire

<u>Step 1: Contextualisation</u>

The Emergency Preparedness report suggests that Category 1 responders should describe the characteristics of the local area that will influence the likelihood and impact of an emergency in the community. The following questions have been defined to explore if an interactive spatial map could help Category 1 responders build up a common understanding of the local risk context.

Q1.1: An ability to explore various **social intelligence** (such as the demographic, ethnic and social composition of the community, the geographical distribution, identification of vulnerable groups, level of community resilience) in an interactive spatial map could help Category 1 responders to establish a collective understanding of the local risk level.

Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1	2	3	4	5

Comment on: What additional social data is important for you to be displayed on the map? How could such social data exploration on an interactive map be useful for multi-agency teams?

Q1.2: An ability to explore the **local environment** and understand the local vulnerabilities, characteristics of the space (urban, rural, mixed), scientific sites, etc. on an interactive spatial map could help Category 1 responders to receive a better collective understanding of the likelihood of, and the impact of, an emergency in the community.

Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1	2	3	4	5

Comment on: What additional data on the local environment is important for you to be displayed on the map? In your view, how could such an interactive exploration of the environment on an interactive spatial map be useful for multi-agency teams?

Q1.3: An ability to explore the **local infrastructure** (transport, utilities, business), the critical supply network and critical services (telecommunication hubs, health, finance, etc.) on an interactive spatial map could help Category 1 responders to receive a better understanding of the likelihood and impact of an emergency in the community.

Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1	2	3	4	5

Comment on: What additional data on the infrastructure is important for you to be displayed on the map? In your view, how could such an interactive exploration of the local infrastructure be useful for multi-agency teams?

Q1.4: An ability to explore **potential hazardous** sites and their relationships to communities or sensitive environmental sites on an interactive spatial map could help multi-agencies to understand the likelihood of, and the impact of, hazardous events in the local area.

Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1	2	3	4	5

Comment on: What hazardous sites are important for you to be displayed on the map? In your view, how could such an interactive exploration of hazardous sites be useful for multi-agency teams?

Q1.5: An ability to visualize a combination of risks **(social, environmental, infrastructure, hazardous sites**) in an interactive map could help Category 1 responders build up an integrated view of the local risk context.

Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1	2	3	4	5

Comment on: What combinations of risks would be useful?

Step 2: Hazard Review

Hazards that present significant risks are identified on the basis of experience, research or other information. These hazards are shared and discussed at LRF meetings with a view to agreeing a list of hazards to be assessed. The following questions have been defined to explore if an interactive spatial map could help Category 1 responders capture experience, intelligence and research data and communicate them to others during hazard review meetings.

Q2.1: Utilising your past experience, An interactive map with appropriate graphical illustrations could be used to represent the likelihood of, and the impact of, hazards?

Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1	2	3	4	5

Comment on: What type of experiences would you like to present on the interactive map to enhance communication and discussion during hazard review meetings?

Q2.2: An interactive map with appropriate graphical illustrations could be used as a medium to present the likelihood of, and the impact of, hazards derived from research data?

Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1	2	3	4	5

Comment on: What type of research data would you like to present on the interactive map to enhance communication and discussion during hazard review meetings? Comment on other types of data that could be beneficial within an interactive map.

Q2.3: The use of an interactive map, integrated with hazard information, could help members of the Risk Assessment Working Group (RAWG) and the Local Resilience Forum (LRF) make careful judgments on which hazards should be included in further assessment.

Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1	2	3	4	5

Comment on: How?

Step 3: Risk Analysis

The purpose of this step is to consider the likelihood of, and the outcome and impact of, a hazard. The Local Risk Assessment Guidance (LRAG) from central government should provide a basis for this work, but the local knowledge available within the Risk Assessment Working Group (RWAG) and other local organisations should allow the RAWG to elaborate on the assessment. The purpose of this section is to explore how the collaboration of both Category 1 responders could be enhanced in elaborating this assessment.

Q3.1: The use of an interactive spatial map to present the local risks' context (social, infrastructure, environmental, hazardous sites) and the outcome of a hazard (derived from computer simulation or experience) could help Category 1 responders to collectively elaborate the assessment of a hazard and measure its impact?

Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1	2	3	4	5

Comment on: What types of simulation data, historical data and experiences could be useful in visualizing on the interactive map and why? How could the integration of the local risks' context and the outcome of hazards be useful?

Q3.2: The use of an interactive spatial map to present the cascading effect would help Category 1 & 2 responders to build up a broader perspective of the outcome of hazards and their impact?

Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1	2	3	4	5

Comment on: What types of cascading effects of hazards will be useful?

Step 4: Risk Evaluation

The production of a risk matrix is an essential part of the risk assessment process. Four risks' ratings (very high, high, medium and low) are used to indicate the risk level.

Q4.1: The representation of risks' ratings on an interactive map could help agencies to have an holistic view of hazards in their local areas.

Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1	2	3	4	5

Comment on: What additional information on the interactive map could be useful at the risk evaluation stage?

<u>Step 5: Risk Treatment</u>

Risk treatment has a number of stages: assess the type and extent of the capabilities required to respond to hazards; identify capabilities in place, consider the capability gaps and the extent of the risks; rate the risk priority; identify additional treatments required to close the capability gaps and manage the risks more effectively; identify whose responsibility it is to provide treatment, etc.

Q5.1: The visualisation of the capabilities required and the capabilities in place on an interactive map would help agencies to collectively understand the capability gaps and address the additional treatments required to close the capability gaps and manage the risks more effectively.

Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1	2	3	4	5

Comment on: What types of capabilities should be modelled and visualized? How could the modelling and visualization of capability data on an interactive map be useful at the risk treatment stage?

<u>Step 6: Monitoring and Reviewing</u>

This stage implies that risks should be monitored continuously and that the previous steps (1 -5) should be repeated when new risks are identified.

Q6.1: The availability of intelligence collected from Step 1 to Step 5 within an interactive map in an integrated form could help Category 1 responders to continuously improve risks' management strategy and build resilient communities.

Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1	2	3	4	5

Comment on: Potential advantages.

Q6.2: Having understood the risks, how do you check if you are prepared for disaster?

Any other comments:

- Potential use in emergency planning
- Potential use in training exercises

Appendix B

Appendix B Interactive Map Evaluation and Questionnaire

Purpose of this interactive map evaluation

This interactive spatial map aims to provide a collaborative environment to support multi-agency collaboration in risk assessment processes. The purpose of this evaluation of an interactive map prototype is to determine the value of an interactive spatial map to enhance multi-agency risk assessment processes in the **assessment & preparedness stages** of the context of Integrated Emergency Management. This evaluation is about enhancing the risk assessment process, collaboration and multi-agency teams' preparedness.

Part 1: Demonstration

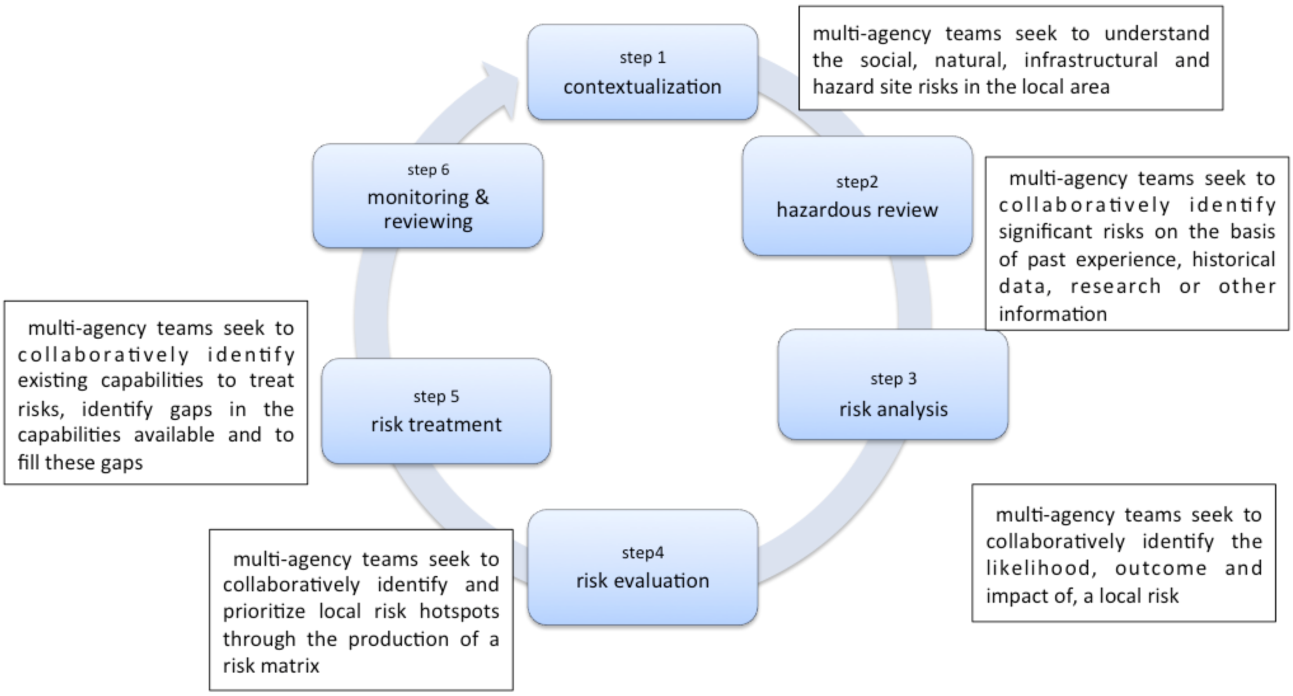
- Objectives of this demonstration: Contextualization; The aim of this section is to demonstrate the system's capabilities to contextualise information such as social, natural and critical infrastructural vulnerability as well as hazard risks' sites in the local area. The system enables the visualization of these combined data sets in an effort to allow collaborative information sharing.

Part 2: The Flood Scenario

Part 3: Discussion

The objective of this discussion is to test how the system could enhance the six-step risk assessment process

Part 4: Answering questionnaire



<u>Appendix B Interactive Map Evaluation and Questionnaire</u>

Participant number ______________________

The interactive spatial map aims to provide a collaborative environment to support multi-agency collaboration in risk assessment processes. The following questions aim to determine the value of the interactive spatial map in enhancing multi-agency risk assessment processes in the **assessment & preparedness stages** of the context of Integrated Emergency Management.

Score the following statements by giving a mark (1 – 5): 1 – Strongly disagree, 2 – Disagree, 3 – Neutral, 4 – Agree, and 5 – Strongly agree.

Part 1: "perceived effectiveness" and impact of the interactive in supporting the risk assessment process

1. Step 1: Contextualization of local risk.

a. Visualization of <u>Social Information</u> on the interactive map

Statement	Marks				
	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1. The visualization of this social information on the interactive map helps multi-agency teams collectively understand local social risks	1	2	3	4	5
a) The visualization of social information helps multi-agency teams understand concentrated social vulnerable spaces in the city.	1	2	3	4	5
b) The visualization of social information helps multi-agency teams understand the demographic, ethnic and socio-economic composition of the community.	1	2	3	4	5
c) The visualization of social information helps multi-agency teams understand the geographical location of various communities within the local area.	1	2	3	4	5
d) The visualization of social information helps multi-agency teams understand the level of preparedness required for coping with demands arising from a potential disaster.	1	2	3	4	5

e) The visualization of population densities helps multi-agency teams place resources that can be used to evacuate residents.	1	2	3	4	5
The visualization of population changes over daytime/night time helps multi-agency teams understand the varying demands in evacuation planning.	1	2	3	4	5
The visualization of ethnic communities who are not well integrated with society helps multi-agency teams identify community leaders who could be used to warn, and inform, their communities during emergencies.	1	2	3	4	5
The visualization of a transient population (travellers' communities, students) helps multi-agency teams to identify and safeguard those communities during emergencies.	1	2	3	4	5

b. Visualization of Local Infrastructure on an interactive map

Statement	Marks				
	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
2. The visualization of this local infrastructure information on the interactive map helps multi-agency teams to collectively understand local infrastructure risks.	1	2	3	4	5
a) The visualization of electrical substation locations and associated colour map helps multi-agency teams understand the number of buildings that would be affected by the loss of a substation.	1	2	3	4	5
b) The visualization of telecom substation locations and associated colour map helps multi-agency teams determine the impact on buildings in the event of the loss of a telecommunication substation.	1	2	3	4	5
c) The visualization of water distribution point locations and associated colour map helps multi-agency teams identify how many buildings and key infrastructures would be affected.	1	2	3	4	5

The visualization of health facility locations helps multi-agency teams identify the health facilities that could be used in emergency situations.	1	2	3	4	5
d) The visualization of heritage buildings & site locations helps multi-agency teams to identify which of these are more vulnerable to risk and to consider protection measures.	1	2	3	4	5
The visualization of major financial institution locations helps multi-agency teams identify critical financial institutions that could be placed in a vulnerable situation.	1	2	3	4	5

Visualization of the Natural Environment on an interactive map

Statement	**Marks**				
	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
3. The visualization of the Natural Environment on the interactive map helps multi-agency teams establish a collective understanding of the important natural resources within the space viewed.	1	2	3	4	5
The visualization of reservoir locations helps multi-agency teams assess and understand the area that would be affected by a potential dam failure.	1	2	3	4	5
The visualization of animal sanctuary locations (and the type and number of animals there) helps multi- agency teams understand the numbers and types of animals that need rehousing.	1	2	3	4	5
The visualization of national park locations helps multi-agency teams understand the impact that a disaster could have on plants, wildlife and on sites of special enivronmental interest.	1	2	3	4	5

c. Visualization of Hazardous Sites on an interactive map

Statement	**Marks**

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
4. The visualization of this hazardous sites' information on the interactive map helps multi-agency teams to collectively understand the local risks imposed by the sites.	1	2	3	4	5
5. The visualization of chemical site locations and the identification of the number of people that could be affected by hazards occurring on these sites helps multi-agency teams identify people living in proximity to a chemical site in order to communicate with, and inform, them.	1	2	3	4	5
6. The visualization of Universities' lab locations helps multi-agency teams understand the types of material being used at these sites and the potential impact during a disaster.	1	2	3	4	5

Layers within the spatial map
Information only: IDS for various visual features.

Social information	Natural Environment	Infrastructure	Hazardous Sites
a. Population densities b. Population changes daytime/night time c. Ethnic communities who are not well integrated with the society and have language difficulties d. A transient population (travellers' communities, students) e. Elderly people f. People with disabilities g. Families with children (infants) h. Pregnant ladies i. Serious medical needs (requiring special medical equipment for evacuation) j. Specific types of illnesses (needs special procedures for evacuation) k. Those with chronic health conditions l. Buildings which host vulnerable people such as hospices and schools	a. Reservoirs b. The topography c. Areas with risks of land slide d. Rivers e. National parks f. Forests g. Animals sanctuaries	a. Electrical substations (Electricity supply networks, Electricity transformers) b. Telecom substations (telecom supply networks, Green boxes, Mobile phone towers and masts, premises containing the data hubs of communications centres) c. Gas substations (Gas supply networks) d. Water distribution points (Water supply networks) e. Pumping stations (Waste water system, drainage system) f. Bridges g. Tram networks h. Rail networks i. Road networks (existing including high ways, major roads) j. Bus stations (bus stops) k. Traffic lights l. Airports m. Major financial institutions n. Shopping centres o. Health buildings; local GPs, Walk-in clinics, Doctors, Nursing homes & Hospitals, Pharmacists p. Residential houses	a. A recycling plant b. Waste disposal sites c. Chemical site (Chemical storage sites, Chemical factory, Oil rich sites) d. Universities' labs Biological, Biometric & Radiological risks

		q. Buildings of interest; Police, Ambulance & Fire stations r. Heritage buildings & sites s. Universities	

Please specify which combinations of layers are useful to you/your organization

Integrated Layers				**The usefulness of the Integrated Layers that you have chosen. (i.e. why you have chosen these layers)**
Social [a-l]	Natural Environment [a-g]	Infrastructure [a-s]	Hazardous Sites [a-d]	
For example ***a, e***	***c***	***f, p***	***d***	***Flood***

2. Step 2: Hazard Review

Statement	Marks				
	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
5. The interactive map helps multi-agency teams capture experience, intelligence and research data and communicate them to others during hazard review meetings.	1	2	3	4	5
The visualization of past data (such as the impact of previous floodings) helps multi-agency teams understand the impact of similar potential emergencies, and assists in learning from past action and the experience of others.	1	2	3	4	5

3. Step 3: Risk Analysis

Statement	Marks				
	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
6. Visualization on the interactive map helps multi-agency teams estimate the likelihood, outcome and impact of hazards in the local area.	1	2	3	4	5
a) The interactive map helps multi-agency teams to collectively understand the outcome of hazards (eg, in the case of a flood, the likelihood of certain hazards occurring and the likely magnitude of such hazards).	1	2	3	4	5
The interactive map helps multi-agency teams to collectively understand the impact of hazards on people, such as the numbers potentially affected by the hazard.	1	2	3	4	5
The interactive map helps multi-agency teams to collectively understand the impact of hazards on critical infrastructure and on the number of buildings affected and on utility services and transport.	1	2	3	4	5

The interactive map helps multi-agency teams to collectively understand the impact of hazards on plants, wildlife and and on sites of special enivronmental interest.	1	2	3	4	5
The interactive map helps multi-agency teams to collectively understand the impact of hazards on the economy of the area affected (eg. the number of shopping centres unable to function because of the loss of electricity due to substation failure).	1	2	3	4	5

4. **Step 4: Risk Evaluation**

Statement	**Marks**				
	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
7. The visualization on the interactive map helps multi-agency teams to collaboratively identify and prioritise risk hotspots in the area in order to produce a risk level matrix (high, medium and low risk)	1	2	3	4	5
The system made it easy to identify risk hotspots in the local area.	1	2	3	4	5
The system made it easy to prioritise these risk hotspots.	1	2	3	4	5
The system made it easy to produce the risk level matrix (showing high, medium and low risk)	1	2	3	4	5
The system made it easy for the group to collaborate on this task.	1	2	3	4	5
The system made it easy to share ideas and to come to an agreement within the group.	1	2	3	4	5

5. Step 5: Risk Treatment

Statement	Marks				
	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
8. The visualization on the interactive map helps multi-agency teams to collaboratively understand their current capabilities to deal with risks and to identify gaps in these capabilities?	1	2	3	4	5
The system will make it easy to identify the number and the type of resources in the local area.	1	2	3	4	5
The system will help in understanding the overall capability of multi-agencies in the local area.	1	2	3	4	5
The system made it easy to keep track of the use of resources.	1	2	3	4	5
The system made it easy for the group to collaborate on this task.	1	2	3	4	5
The system made it easy to share ideas and to come to an agreement within the group.	1	2	3	4	5

6. Step 6: Monitoring and Reviewing

Statement	Marks				
	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
9. The interactive map helps multi-agency teams to collaboratively update, review and maintain information regarding local risks.	1	2	3	4	5

a. The interactive map would help the ongoing monitoring of risks.	1	2	3	4	5

Part 2: "perceived effectiveness" of the interactive map for successful interactive and for strengthening the collaboration between multi-agencies.

Statement	**Marks**				
	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
a) The interactive map enhances the interaction between multi-agency teams in terms of decision-making, communication and coordination.	1	2	3	4	5
b) The interactive map helps teams to take turns in expressing their views.	1	2	3	4	5
c) An interactive map system is helpful for multi-agency teams to build up a common understanding of the potential local risks.	1	2	3	4	5
d) An interactive map system can improve the efficiency of communicating ideas and information.	1	2	3	4	5
e) An interactive map system has real value as a tool where there is a need to communicate complex agendas to multi-agency teams.	1	2	3	4	5
f) An interactive spatial map enhances the interpretation skills between multi-agency teams (such as breaking goals into sub-goals and questioning deeply).	1	2	3	4	5
g) An interactive map enhances the reasoning skills between multi-agency teams in terms of a user's ability to think logically, justify priority levels, etc.	1	2	3	4	5
h) An interactive map enhances the assessment skills between multi-agency teams in terms of a user's ability to rationally weight options.	1	2	3	4	5
i) An interactive map enhances the meta-cognitive skills between multi-agency teams in terms of producing multiple ideas and dealing with the incident that has happened when making decisions.	1	2	3	4	5

j)	An interactive map enables users in multi-agency teams to look beyond the first obvious explanations to consider alternative interpretations.	1	2	3	4	5
k)	An interactive map enables users in multi-agency teams to use mental imagery to evaluate plans.	1	2	3	4	5

Please answer the following questions about the system you have just used.

1. How would this system support your current risk assessment activities?

2. Please state what you liked about the system?

3. Please state what you disliked about the system?

4. How do you think the system could be improved?

5. How did your actual experience of the system compare with your initial expectations?

6. Did the system help you to collaborate with the other participants? If yes, please explain why.

7. Any other comments?

Thank you very much for your participation.

Appendix B Interactive Map Evaluation and Questionnaire

Consent Form
Project: PhD Project – Interactive map evaluation

To be completed by the volunteers: We would like you to read the following questions carefully.

Do you understand that you are free to withdraw from this study:

- At any time YES/ NO
- Without giving a reason for withdrawing YES/ NO

Do you agree to take part in this study? YES/ NO

Have you read the information sheet about this study? YES/ NO

Have you had an opportunity to ask questions and discuss this study? YES/ NO

Have you received satisfactory answers to all your questions? YES/ NO

Have you received enough information about this study? YES/ NO

Do you agree to the data being stored and used in the researcher's ongoing research? YES/ NO

Do you agree to the data being stored indefinitely? YES/ NO

Do you agree to let us make transcripts of your answers and present them anonymously in printed publications? YES/ NO

Do you agree to the questionnaire data being shared with academic collaborators on the project at University of Salford? YES/ NO

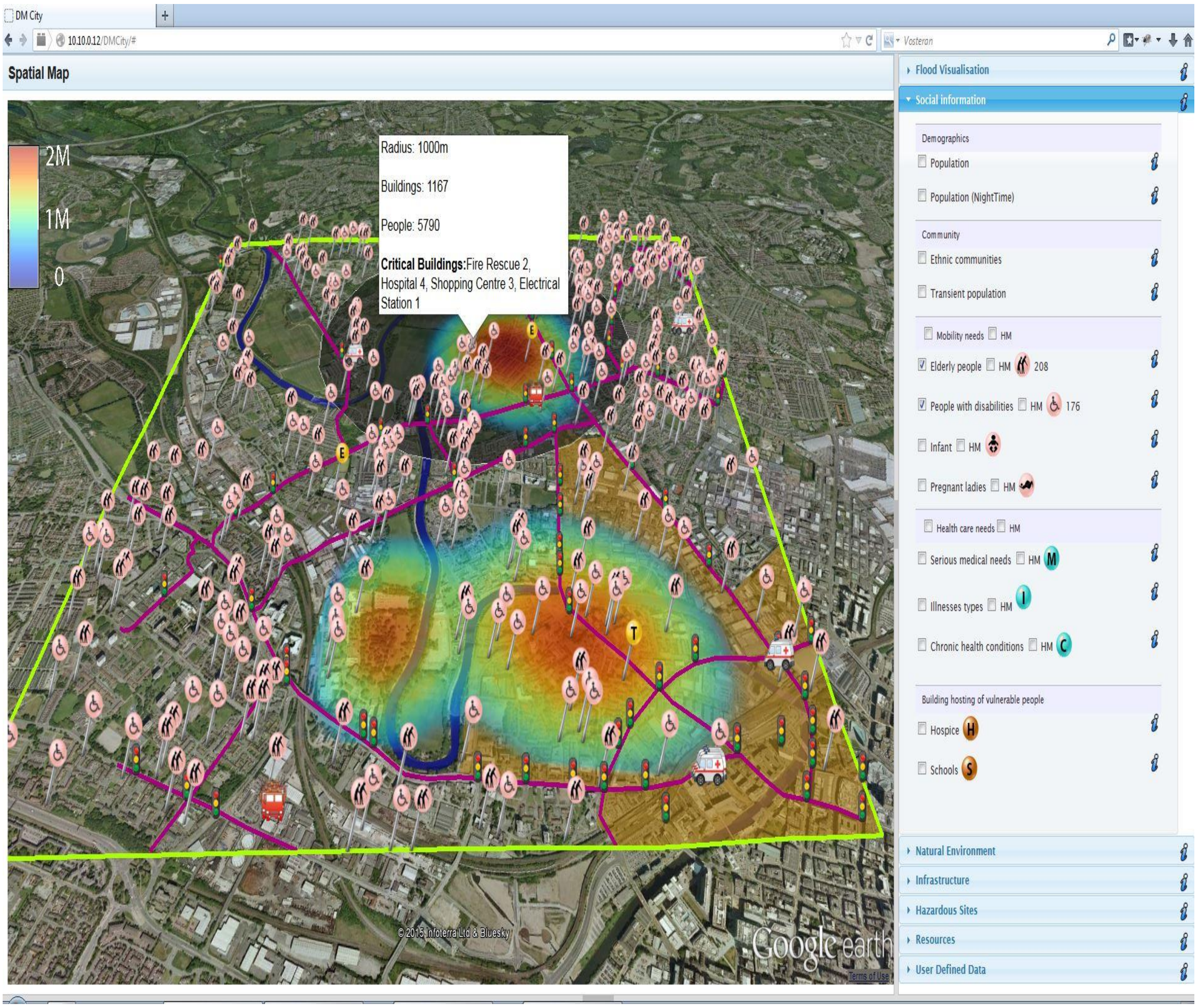
Signed……………………………….Date……………………………...

Name in block letters.……………………………………………………...

Appendix B Interactive Map Evaluation and Questionnaire

The Flood Scenario

1. We have had a report from the Met office that warns of heavy rain in the Salford area.
2. When we compare the projected figures with the Environment Agency's simulation data we detect that there is a potential issue.
3. We will now visualise this data using our system.
4. We can see from the heatmap representing the Environment Agency's simulation data that there will be flooding in three locations.
5. Using our systems social information we can now visualise vulnerable people in the affected areas such as the elderly and disabled.
6. We now overlay critical infrastructure such as electricity sub stations, telecommunications, major roads and traffic lights.
7. Then the areas that will be affected if these critical services fail. Each area also shows critical statistics for each outage area.
8. We now add hazardous sites and show their affected areas. We can again access critical statistics.
9. Resources in these areas can now be added such as Fire and Ambulance stations.
10. Once we have all of this data visualised we have a possible worst case scenario.
11. We can now examine the data for any potential issues or hotspots and create our own notes and markers on the map.
12. The next step in our development will be to create a configuration file that can be passed between partners with visualised settings and notes saved allowing for a more collaborative approach to disaster preparation.


DM City
10.10.0.12/DMCity/#
Spatial Map
2M
1M
0
Radius: 1000m
Buildings: 1167
People: 5790
Critical Buildings:Fire Rescue 2, Hospital 4, Shopping Centre 3, Electrical Station 1
Flood Visualisation
Social information
Demographics
Population
Population (NightTime)
Community
Ethnic communities
Transient population
Mobility needs HM
Elderly people HM 208
People with disabilities HM 176
Infant HM
Pregnant ladies HM
Health care needs HM
Serious medical needs HM
Illnesses types HM
Chronic health conditions HM
Building hosting of vulnerable people
Hospice
Schools
Natural Environment
Infrastructure
Hazardous Sites
Resources
User Defined Data
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Google earth

Contextual Menu Elements