A GRID-AWARE EMERGENCY RESPONSE MODEL FOR NATURAL DISASTERS

by

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Abstract

Natural phenomena are essential and unavoidable planetary actions. When they occur in extreme forms they may have a disastrous impact on human life, property and the environment. Emergency management bodies mitigate, prepare for, respond to and recover from such events. Emergency response is a sum of decisions and actions taken through the collaboration and cooperation of many specialists from different disciplines. However, primary and secondary research findings suggest that there are limitations in the current information and communication technologies (ICT), which affect the effectiveness and efficiency of emergency response tasks. Therefore, the focus of this research was to investigate whether the appropriate use of cutting-edge ICT (such as the Grid) can improve the effectiveness and efficiency of emergency response operations for natural disasters.

The approach adopted in the research involved literature reviews, case studies, face-to-face structured interviews with emergency management stakeholders and ICT experts, model development using Soft Systems Methodology (SSM) linked to Information Systems Development Methodologies (ISDMs), and finally, one-to-one evaluation exercises. Case studies and interviews involving two member states of the European Union were carried out to investigate current practices and to highlight the limitations that emergency management stakeholders face during response operations. SSM was used to investigate the problem area and to produce a conceptual Emergency Response Model (ERM). Further literature review and interviews suggested the Grid as the most appropriate technology to support the ERM. The linking together of the SSM findings with ISDMs - resulted in the production of a Grid-Aware Emergency Response Model (G-AERM) for natural disasters.

The evaluation of the G-AERM demonstrated the applicability of Grid technology to emergency response by supporting stakeholders in monitoring, planning, controlling and managing actions within emergency situations caused by natural disasters in a far more informed way in terms of effectiveness and efficiency. Most importantly, the evaluation

of the G-AERM demonstrated that its architecture is technologically correct, feasible and addresses the key limitations of current ICT in use that have been previously experienced by emergency management stakeholders.

It can be concluded that the G-AERM for natural disasters supports the collaborative and dynamic provision of all available resources and instrumentation towards the accomplishment of emergency response tasks. This has been achieved by making provision for collecting, storing and integrating data from multiple distributed and heterogeneous ICT sources in a seamless and dynamic way. The approach adopted in the G-AERM architecture allows stakeholders to be part of a wider Virtual Organisation (VO) to identify and select choices from the far wider range of resources available. Clearly, this may increase the possibilities for decision makers to take and issue more informed decisions of a collaborative nature towards the accomplishment of issued tasks in a far more effective and efficient way.

Finally, the G-AERM architecture can serve as the specification framework for the production of relevant real-world applications. Such real-world implementations will have implications in the local and wider community. They may uncover scenarios of a cross-disciplinary nature – which an organisation may or may not wish to address - that have been previously regarded as intractable because of (organisations') interaction, size and complexity. For example, there will be a requirement for organisations to share their data with others across the technical infrastructure. It may lead to digitisation of paper-based data and manual processes in order to enhance the availability of resources via the G-AERM infrastructure. It will lead to the need for users' training in order to take advantage of G-AERM's full potential. Last but not least, the implementation phase may prove a challenging experience for stakeholders and computer scientists because of G-AERM's complexity and scale.

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Acronyms

AG	Access Grid
API	Application Programming Interface
ARCOM	Association of Researchers in Construction Management
CEOS	Committee on Earth Observation Satellites
CIA	Central Intelligence Agency
CITC	Construction In the Twenty First Century
CP	Civil Protection
CPOC	Civil Protection Operations Centre
CPU	Central Processing Unit
CRED	Centre for Research on the Epidemiology of Disasters
CSS	Cascade Style Sheets
DAISGR	Data Access and Integration Service Grid Register
DNS	Domain Name System
DQP	Distributed Query Processing
DSS	Decision Support Systems
EADRCC	Euro-Atlantic Disaster Response Coordination Centre
EADRU	Euro-Atlantic Disaster Response Unit
EAPC	Euro-Atlantic Partnership Council
EC	European Commission
EGEE	Enabling Grids for E-science in Europe
EM	Emergency Management
EMA	Emergency Management Australia
EM-DAT	Emergency Disaster Database
EMS	Emergency Management Section
EOS	Earth Observing System
ER	Emergency Response
ERC	Emergency Relief Organisation
ERM	Emergency Response Model
EU	European Union
EUCP	Civil Protection of the European Union
FEMA	Federal Emergency Management Agency

G-AERM	Grid-Aware Emergency Response Model
GDS	Grid Data Service
GDSF	Grid Data Services Factory
GGF	Global Grid Forum
GIS	Geographical Information Systems
GPS	Global Positioning Systems
GRIP	Grid Interoperability Project
GSCP	General Secretariat of Civil Protection
GSI	Grid Security Infrastructure
GSM	Global System for Mobile (Communication)
GSPI	Grid Services Portal Interface
GUI	Graphical User Interface
GWSB	Grid and Web Services Broadcaster
HPC	High Performance Computing
HTML	HyperText Mark-up Language
HTC	High Throughput Computing
HTTP	Hypertext Transfer Protocol
IA	Intelligent Agents
ICDO	International Civil Defense Organisation
ICT	Information and Communication Technologies
IDNDR	Internationally Agreed Glossary of Basic Terms Related to Disaster Management
IDRC	International Disaster Reduction Conference
INMARSAT	International Mobile Satellite Communication
IS	Information Systems
ISDM	Information Systems Development Methodologies
ISDN	Integrated Services Digital Network
LAN	Local Area Network
MAS	Multi-Agent Systems
MP	Members of Parliament
MSS	Management Support Systems
NATO	North Atlantic Treaty Organisation

NEES	Network for Earthquake Engineering Simulation
NEHRP	National Earthquake Hazards Reduction Program
NOC	National Observation Centre
NRC	National Research Council
OCHA	Office for Coordination of Humanitarian Affairs
OGSA	Open Grid Services Architecture
OGSA-DAI	Open Grid Services Architecture – Data Access and Integration
OGSI	Open Grid Service Infrastructure
OU	Operational Unit
OWL	Web Ontology Language
PDA	Personal Digital Assistant
PKI	Public Key Infrastructure
PM	Prime Minister
PSCD	Product Supplier Catalogue Database
QoS	Quality of Service
SA	Security Authentication
SCPC	Senior Civil Planning Committee
SDK	Software Development Kits
SDO	Inter-Ministerial Coordination Body
SOA	Service-Oriented Approach
SOAP	Simple Object Access Protocol
SQL	Structured Query Language
SSL	Secure Sockets Layer
SSM	Soft Systems Methodology
SSO	Single Sign-On
SWOT	Strengths, Weaknesses, Opportunities and Threats
T	Transformation
TCP	Transfer Control Protocol
TIP	Transfer Internet Protocol
UDDI	Universal Description Discovery and Integration
UK	United Kingdom
UN	United Nations

UNICEF	United Nations Children's Fund
UN-DHA	Department of Humanitarian Affairs of the United Nations
UN-ECLAC	United Nations Economic Commission for Latin America and the Caribbean
VHF	Very High Frequency
VO	Virtual Organisation
VSERU	Victoria State Emergency Response Unit
W	Worldview
WAN	Wide Area Network
WSDL	Web Services Description Language
WSRF	Web Services Resource Framework
WWW	World Wide Web
W3C	World Wide Web Consortium
XML	Extensible Mark-up Language

Chapter 1 Introduction

1.1 Introduction

This chapter introduces the focus and the organisation of the research work. It begins with a brief discussion of the background to the research and continues by justifying the need for the research and by outlining its aim and objectives. Finally, it concludes with the structure of the thesis, presenting a chapter-by-chapter outline.

1.2 Background

Natural phenomena are 'necessary planetary actions, which may cause disastrous results to the human life, property and the environment' (Asimakopoulou et al, 2004). Recently, the number of losses caused by natural disasters has increased (Lekkas, 2000; UN, 2000; Shaw, 2003; and Gupta, 2003). As humans are not always capable of avoiding nature and its planetary actions, there is a need to prepare and plan in advance their actions in response to these events in order to protect lives, property and the environment. On this basis, various emergency management bodies involving authorities at a local, national and international level have been formed to mitigate, prepare for, respond to and recover from such disasters.

Such authorities consist of many different professionals from different disciplines and with different areas of expertise. Bringing in expertise from different parties is essential, as this will assist in managing emergency situations in a more informed and holistic approach. However, this may also lead to numerous misunderstandings, 'as each one of the involved parties has their own perception, instrumentation, terminology and code of practice to handle particular situations' (Buckle et al, 2003). This may lead to major breakdowns in communication and practice, which in the particular field of emergency management could lead to important losses, such as human lives, and serious implications for local and international resources and economies. Therefore, the way professionals and specialists contribute their knowledge and experience has to be organised and structured carefully. However, even the best-structured technique can prove unsuccessful if it is not communicated effectively. The need to bring together the intellectual resources of the parties involved within the same environment and to communicate them effectively and efficiently towards the achievement of a particular goal has led to the development of relevant computer-based collaboration systems.

However, there is still room for improvement, as 'many departments and organisations cannot share data and do not use compatible technologies and terminologies' (McQuay, 2003). According to Graves (2004) 'the biggest challenge to emergency responders adopting collaboration tools is the lack of interoperability standards'. In addition to this, they need to process a vast amount of information in a timely fashion, as well as the ever present risk of 'Information and Communication Technologies (ICT) breaking down during crisis' (McQuay, 2003).

At the intersection of the current technologies, and for the above-mentioned conflicts to be overcome, the concept of Grid computing has emerged. In brief, Grid technology 'aim to alleviate the incompatibilities of computing hardware and software and to utilise the full potential of each existing technology in use' (Foster and Kesselman, 2004). Thus, a series of Grid-based applications are already in use in highly demanding disciplines, such as in bio-medicine, in earthquake engineering, in space exploration and many more are under development. The combination of many existing technologies together with continuous technological developments in the field of emergency management could provide improved methods for managing the situation in a more informed and holistic approach, using dynamic and distributed collaboration tools.

1.3 Justification of the Research

Over the last four decades, scientific knowledge related to the intensity and distribution in time and space of natural disasters and the technological means of confronting them has been expanded greatly. While people cannot prevent an earthquake or a hurricane from occurring, or a volcano from erupting, they can apply the scientific knowledge and technical know-how that they already have to increase the earthquake resistance of infrastructures, to issue early warnings on volcanoes and cyclones and organise proper community response to such warnings (Unesco, 2006). The organisation and action of response to warnings and to actual catastrophic events are included in the responsibilities of the emergency management discipline and the authorities responsible to operate in line with its aims. Michalowski (1991) points out that 'emergency management requires flexibility in decision support and ability to respond to varying situations because the scale of the residual effects varies according to the type and scale of the disaster'.

Bringing in expertise from different parties is essential as informed and holistic emergency response 'involves multiple organisations and teams, geographically distributed operations and a high need for coordinated control and decision making' (Graves, 2004). However, during emergency response operations 'the team members often hardly know each other and frequently have to work co-located'. A crisis team has to perform 'many tasks partly in parallel, partly in series during fighting a disaster' (Rijk, and Berlo, 2004). Literature and lessons learned from past events show that in order for a successful response operation to unplanned incidents, involved parties should have a common understanding and knowledge, should have access to relevant data and expertise, as well as they should be able to make collaborative assessments towards decision-making. Finally, up to date information about current situation, decisions and plans of work should be communicated between relevant and locally distributed parties.

In the specific context of emergency response management, electronic based methods for communication and management involve the process of exchanging information digitally (Howard et al, 2002). Currently, electronic systems enable users to communicate via e-mail, office networks and project extranets. According to Unesco (2006) 'modern technologies have been developed in order to reduce the exposure of the physical and built environment and the other elements of socio-economic life to extreme natural phenomena and disasters'. In general, relevant collaborative computer-based systems have been developed to support emergency response operations and these aim to form appropriate computerised environments in order to overcome human cognitive limitations and to provide decision makers with a holistic view of the concerned situation so they can manage it (Turban and Aronson, 2001; Maracas, 2002).

However, many emergency management departments and organisations cannot share data or often, critical information is present but hidden in the "noise" due to information overload (Turoff 2002). This is quite common in computer-based communication systems. Conventional ICT are not able to support diverse and complex exchange of dynamic information, as this is required during an emergency. In addition to this, ICT continue to breakdown during crisis. 'During a major incident many segmented organisations must come together to plan, coordinate and manage a coordinated response to the incident. Sharing of accurate information in a timely manner – while limiting redundant requests and replies for the same information – is essential for an effective coordinated response' (Graves, 2004). Overall, recent emergency management approaches are characterised as inefficient 'because of their unstructured poor resource management and centralised nature with fixed hierarchical instructions' (Scalem et al, 2005). Thus often, 'people must take life and death decisions and take actions based upon incomplete information' (Alles et al, 2004).

In tackling these ICT related problems, the latest developments with regard to networking and resource integration have resulted in the new concept of Grid technology. Grid computing refers to an emerging infrastructure designed to enable the flexible, secure, co-ordinated sharing of processing power, data or other types of resources to be used for large-scale and/or intensive problem solving purposes among a dynamic collection of resources including individuals or teams. Moreover, Grid technology has been described as the 'infrastructure and a set of protocols to enable the integrated, collaborative use of distributed heterogeneous resources including high-end computers, networks, databases, and scientific instruments owned and managed by multiple organisations, referred to as Virtual Organisations' (Foster, 2002). A Virtual Organisation (VO) is formed 'when different organisations come together to share resources and collaborate in order to achieve a common goal' (Foster et al, 2002). The added value that Grid computing provides, as compared to conventional distributed systems, lies in the ability of the Grid to allocate and re-schedule resources dynamically in real-time according to the availability or non-availability of optimal solution paths and computational resources. Should a resource become compromised, untrustworthy or simply prove to be unreliable, then 'dynamic re-routing and re-scheduling capabilities can be used to ensure that the quality of service is not compromised' (French et al, 2007). Finally, the Grid is a type of a parallel and distributed system that enables the sharing, selection, and aggregation of resources distributed across multiple administrative domains based on their availability, capability, performance, cost, and users' quality of service requirements (Goyal, 2005).

Limitations of current ICT in use during emergency response management adversely affect the effective and efficient accomplishment of tasks in relation to the set of requirements that emergency management stakeholders have. However, there are a number of Grid-related methods, which potentially could be employed to assist addressing limitations of current ICT in use, in a way that could alleviate adverse effects caused by ICT limitations and assist in a more effective and efficient accomplishment of tasks in relation to emergency response management. The deployment of Grid technology could facilitate seamless access to what is possibly known and available in a distributed environment in a given timeframe, which in turn will enlarge the search space boundary. Overall, it is believed that this deployment could facilitate methods towards normative thinking as required to support emergency response stakeholders to work remotely and collaboratively in order to plan, control, coordinate and communicate relevant actions in a more effective and efficient way.

1.4 Aim and Objectives of the Research

There is room for improving the collaboration, planning, control, coordination and communication of the relevant authorities involved in the response phase of emergency management when there is a disaster caused by the occurrence of an extreme natural catastrophic phenomenon. Thus, the aim of this research is:

- To study the feasibility and applicability of Grid technology to emergency management such that stakeholders can monitor, plan, control and manage actions within an emergency situation caused by natural disasters in a more informed way.

The specific objectives of this research work include:

1. Review of natural catastrophic phenomena, the implications of their occurrence on human life, property and the environment, as well as emergency management processes;
2. Review of current information and communication technologies (ICT) that the emergency management stakeholders use during emergency situations caused by natural disasters, with a particular focus on emergency response operations;
3. Review of Grid and other emerging technologies, as mechanisms to support the improvement of the effectiveness and efficiency of collaboration, coordination and communication between the relevant authorities when a natural disaster causes emergency situations;
4. Development of a Grid-aware emergency response model (G-AERM) based on the effective use of appropriate management procedures and Grid technology;
5. Evaluation of the conceptual model to establish its effectiveness and efficiency.

1.5 Research Methodology

This sub-section is concerned with the research methodology and methods used throughout the research for the gathering and assessment of relevant information and for the development and evaluation of the proposed Grid-Aware Emergency Response Model (G-AERM).

Soft Systems Methodology (SSM) was adopted as the most appropriate methodological approach for this research. SSM epistemology and its proposed methods employed throughout the study. Literature review was used for gathering relevant information about natural disasters, emergency management and Grid technology. This assisted, firstly in understanding the complex area of emergency management and in particular, the phase of emergency response for natural disasters and secondly, in the identification of the problem area. Further to this, the literature review provided information about current ICT in use during emergency response operations and about the nature of Grid technology through the review of its components and current Grid applications in a variety of disciplines. Case studies of two member states of the European Union (EU) – Greece and the United Kingdom (UK) – further established the problem area. One-to-one structured interview exercises with emergency management stakeholders of the aforementioned two countries revealed the exact ICT related problems they face during emergency response operations and these assisted in the identification of the user requirements of the proposed solution.

SSM modeling techniques were employed for the formulation and evaluation of the Emergency Response Model (ERM) for natural disasters. Further to this, the ERM has been incorporated with Grid components by linking together SSM findings with ISDMs – which have been identified by literature review and one-to-one interview exercises with Grid technology experts – providing the Grid-Aware Emergency Response Model (G-AERM). The G-AERM aims to serve as an improved way of planning, controlling, coordinating and communicating actions between emergency management stakeholders during emergency response operations. Evaluation of the G-AERM for natural disasters has been carried out aiming to test its effectiveness and efficiency. One-to-one interview exercises have been carried out with a group of emergency management stakeholders – representing Greece and the UK – and with a group of Grid technology experts. It is believed that this approach provides a holistic evaluation of the proposal.

Figure 1.1 illustrates the organisation of the research and its objectives as these have been established in section 1.4.

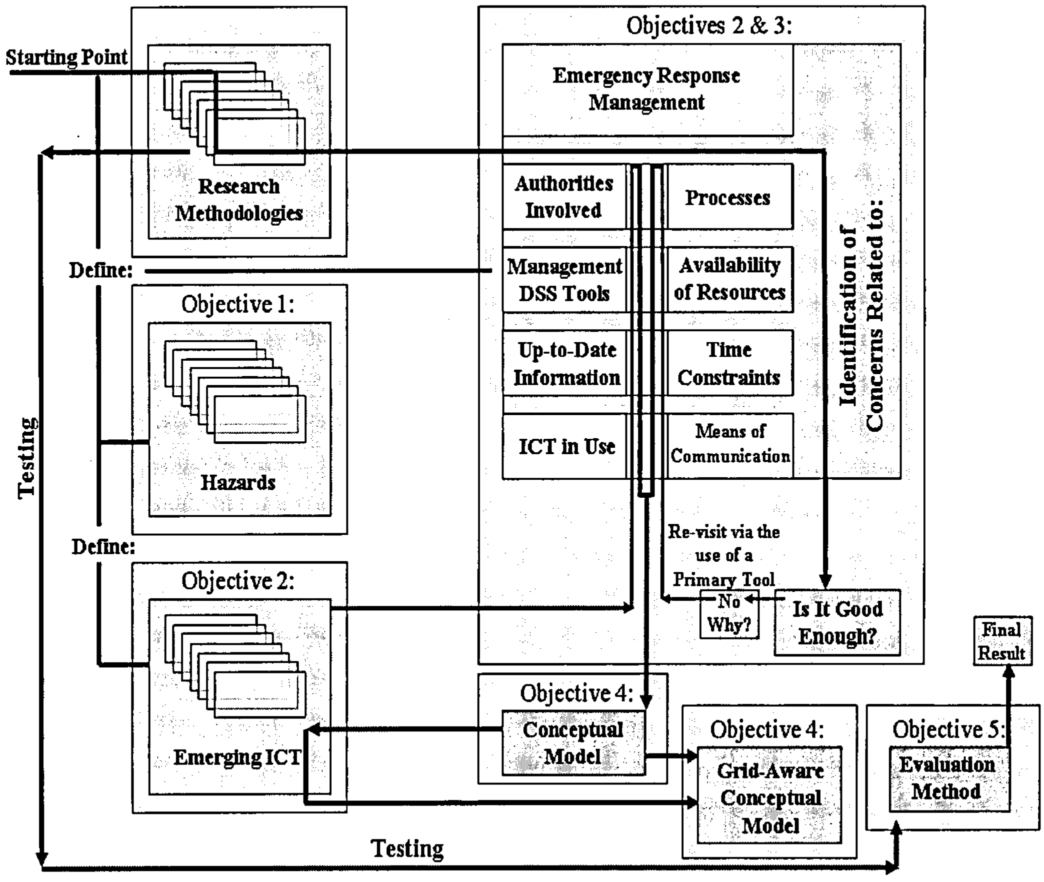


Figure 1.1: Graphical Representation of the Work Plan

1.6 Structure of the Thesis

The thesis consists of nine chapters and five appendices, as described below:

- **Chapter 1 Introduction**

Chapter 1 introduces the area of investigation, presents the background to the research and justifies the need for the research to take place. Further to this, it presents the methodological approach and the structure of the thesis.

- **Chapter 2 Research Methodology**

Chapter 2 explores the available research methodologies, in order for the appropriate approach for the nature of the present study to be identified. It defines and presents the quantitative and qualitative research methodologies, along with their methods. The distinction between hard and soft approaches is made and reasons given for the adoption of Soft Systems Methodology (SSM) to tackle the research problem.

- **Chapter 3 Natural Disasters and Emergency Management**

Chapter 3 is concerned with the natural phenomena that have a disastrous impact on human life, property and the environment. It presents the disciplines responsible for the management of the consequences of these events with particular reference to the emergency response phase of disasters. Constraints in the management of natural disasters are also discussed.

- **Chapter 4 Case studies of Emergency Management in Europe**

Chapter 4 presents a series of case studies from selected countries – member states of the European Union (EU), so to provide an insight into the content of phase emergency response management processes. It also identifies the ICT used by the emergency management stakeholders during response operations. The limitations and problems of these methods are also discussed based on a series of structured interviews.

- **Chapter 5 The Soft Systems Methodology Conceptual Emergency Response Model (ERM)**

Chapter 5 integrates the outputs from Chapters 3 and 4 along with the support of SSM. Integration of these findings led to the development of the conceptual ERM, which serves the emergency management stakeholders during emergency response operations to natural disasters. The ERM is created, described and refined in line with the problems identified by literature review and by one-to-one interview exercise with emergency management stakeholders.

- **Chapter 6 Enabling Grid Technology**

Chapter 6 presents a literature review of emerging technologies, highlighting the potential of distributed technologies in the field of emergency response. It presents the concept of Grid technology with details of its technical components. A series of structured interviews with Grid experts is also presented. Chapter 6 concludes that Grid technology is serving as a complete solution to the demands of the proposed SSM conceptual emergency response model.

- **Chapter 7 The Grid-Aware Emergency Response Model (G-AERM) for Natural Disasters**

Chapter 7 further develops the earlier findings enriching the conceptual ERM resulting from the Soft Systems Methodology enquiry – by linking together SSM findings with ISDMs – with Grid technology and proposes the Grid-Aware Emergency Response Model (G-AERM) for natural disasters.

- **Chapter 8 Evaluation of the Model**

Chapter 8 is concerned with the evaluation of the G-AERM in terms of its effectiveness and efficiency. It describes the evaluation procedures, which involved both emergency management stakeholders and Grid experts. It critically presents the findings and makes proposals for the further development of the Grid-aware model.

- **Chapter 9 Conclusions and Recommendations**

Chapter 9 summarises the whole thesis, presents the main conclusions and limitations of the research. It also recommends proposals for further work and research in the field.

- **Appendices**

The thesis contains five appendices as follows:

- **Appendix I**

Appendix I presents the list of publications derived by the research.

- **Appendix II**

Appendix II is concerned with the primary tool used for the investigation of the problem area. In particular, it presents details of the primary research tool one-to-one interviews that were conducted with the emergency management stakeholders, including their expertise and the list of interview questions.

- **Appendix III**

Appendix III presents the primary tool used in order for the most appropriate technological solution to be identified and incorporated into the proposed conceptual model. This includes one-to-one structured interviews that were conducted with information and communication technology professionals, with particular expertise in Grid technology. The appendix presents the details of the participants, the contact medium (e-mail) and the list of questions.

- **Appendix IV**

Appendix IV demonstrates the first tool created and used for the evaluation of the proposed G-AERM in terms of its effectiveness and efficiency. In particular, it presents the details of the emergency management stakeholders, along with their expertise, the contact medium (e-mail), as well as the one-to-one structured interviews – including questions and answers – that the participants provided for the research work.

- **Appendix V**

Appendix V presents the details of the evaluation exercise of the G-AERM architecture. In particular, it presents the expertise and details of the evaluation participants and the one-to-one interview questions, along with the answers provided.

1.7 Summary

This chapter has briefly presented the background to the research, its justification, the aim and the objectives of the study and the methodology used. The thesis structure was also presented. The next chapter discusses in detail the research methodology.

Chapter 2 Research Methodology

2.1 Introduction

This chapter is concerned with an exploration of research approaches and methodologies in order to identify the most appropriate for this research. This begins with a definition of the relevant terms, such as "research", "research methodologies" and "methods". Then, the identification of the broader area containing the particular research problem is established. The different types of research methodologies are then discussed, including the differences between "hard" and "soft" approaches. The chosen research methodology and its methods are described in detail and a justification provided for their use.

2.2 Definitions

This section is concerned with the establishment of the definitions of the terms "research", "research methodologies" and "methods", as well as with the brief presentation of some of these approaches, with particular focus on quantitative and qualitative methods.

Research is 'a "flow of work" that evolves over the entire course of any investigative project' (Strauss and Corbin, 1998). Its purpose is to 'add to the body of established knowledge by addressing some of the myriad unanswered questions' (Remenyi and Williams, 1995). In order for this process to be organised and structured some research methodologies have been formed. According to Strauss and Corbin (1998) the term "methodology" 'refers to a way of thinking about and studying reality'. In particular, it stands as 'an operational framework, within which the facts are placed so that their meaning may be seen more clearly' (Leedy, 1989). The term "methodology" refers to more than a simple set of methods. It refers to the rationale and the philosophical assumptions that underlie a particular study. Expanding on this, Bowman (2004) points out that a 'methodology is a strategy for overcoming the problems faced by the systems analyst'.

According to Glaser and Strauss (1967), Bryman (1988), Maykut and Morehouse (1994), Strauss and Corbin (1998), Bowman (2004), Checkland and Scholes (1991) and others, methodology is a way of thinking. To exemplify this is to say that the term "methodology" is defined as 'the analysis of the principles of methods and rules employed by a discipline; the development of methods, to be applied within a discipline; and a particular procedure or set of procedures' (Neill, 2007). A methodology includes concepts, as these are related to a particular discipline or field of inquiry. These include a collection of theories, concepts or ideas; a comparative study of different approaches; and a critique of the individual methods.

The term "method" refers to the set of procedures and techniques for gathering and analysing data. In particular, methods include 'an informal, but strict set of rules that have evolved to ensure the integrity, reliability and reproducibility of the work' (Remenyi and Williams, 1995). Most disciplines have their own specific methods, which support the methodologies. Therefore, some may argue that methodologies consist of methods. Thus, a research methodology is made up of methods, which include techniques, tools, conventions and documents and it lays down the tasks to be done during research. Later on in this chapter the establishment of such methods takes place, accompanied by the reasons that they have been employed for the particular problem area of the study. However, at this point it is considered useful to describe the most common research methods used. These include quantitative and qualitative methods.

2.2.1 Quantitative and Qualitative Research Methods

Research methods can be classified in various ways; however 'one of the most common distinctions is between quantitative and qualitative research methods' (Myers, 2007). This section presents both quantitative and qualitative research approaches, along with their techniques and tools to address different types of research problems; and it highlights their main differences.

2.2.1.1 Quantitative Research

Quantitative research was originally developed in the natural sciences in order to study natural phenomena. Examples of quantitative methods, which 'have now been adopted by the social sciences; include survey methods, laboratory experiments and numerical methods such as mathematical modelling' (Gefen and Boudreau, 2004).

According to Huysamen (1997) descriptions of quantitative research 'typically discern a cycle of successive phases of hypothesis formulation, data collection, analysis and interpretation'. Quantitative research tries to establish facts, make predictions and test hypotheses, which have already been stated. Expanding on this one may say that quantitative research is 'the systematic scientific investigation of quantitative properties and phenomena and their relationships' (Neill, 2007). It is widely used in both the natural and social sciences. A large part of the data analysis of quantitative research is statistical, 'striving to show that the world can be looked at in terms of one reality; this reality, when isolated in context, can be measured and understood, a perspective known as positivism' (Gay and Airasian, 1999). Quantitative researchers are those who 'treat their objects of study as having an existence independent of themselves and without any intrinsic meaning' (Huysamen, 1997). In addition to the above, quantitative research also 'involves analysis of numerical data' (Neill, 2007).

2.2.1.2 Qualitative Research

The term "qualitative" implies 'an emphasis on processes and meanings that are not rigorously examined, or measured, in terms of quantity, amount, intensity, or frequency' (Denin and Lincoln, 1998). Qualitative research is 'a multi-method in focus, involving an interpretive, naturalistic approach to its subject matter' (Maykut and Morehouse, 1994). This means that qualitative researchers study things in their natural settings, attempting to make sense of, or interpret, phenomena in terms of the meanings people bring to them. This type of research involves the studied use and collection of a variety of empirical materials such as case study, personal experience, introspective, life story, interview, observational, historical and interactive texts. These may describe 'routine and problematic moments and meanings in individuals' lives' (Denin and Lincoln, 1998). Strauss and Corbin (1998) further explain qualitative research as 'the type of research in which findings are not arrived at by statistical procedures or other means of quantification'. It can refer to research about persons' lives, lived experiences, behaviours, emotions and feelings, as well as about organisational functioning, social movements, cultural phenomena and interactions between nations. The qualitative researcher seeks patterns, which come out of or emerge from the data. The researcher 'makes a guess or forms a hypothesis which is then used to test the data' (Maykut and Morehouse, 1994). The importance of this method is that it 'provides a sense of vision, where it is that the analyst wants to go with the research' (Strauss and Corbin, 1998). The techniques used during this process provide the means for bringing that vision into reality. The value of this method lies in its ability not only to generate theory, but also to ground that theory in data. There are three major components of qualitative research and these include:

- Data, which can come from various sources, such as interviews, observations, documents, records and films;
- Procedures the researcher can use to interpret and organise the data. They usually consist of conceptualising and reducing data, elaborating categories in terms of their properties and dimensions and relating through a series of prepositional statements; and
- Written and verbal reports (Strauss and Corbin, 1998).

2.2.1.3 Evaluation of Research Outputs using Quantitative and Qualitative Methods

Every research study must be evaluated 'in terms of the canons and procedures of the method used to generate the research findings' (Strauss and Corbin, 1998). Qualitative researchers stress the socially constructed nature of reality, the intimate relationship between the researcher and what is studied and the situational constraints that shape enquiry. Such researchers emphasise the value-laden nature of inquiry. They seek answers to questions that stress how social experience is created and given meaning. In contrast, quantitative studies emphasise the measurement and analysis of causal relationships between variables, not processes. Inquiry is purported to be 'within a value-free framework' (Denin and Lincoln, 1998). Qualitative evaluation inquiry draws on 'both critical and creative thinking – both the science and the art of analysis' (Patton, 1990). The ability to reproduce findings gives the original findings credibility. However, reproducing social phenomena can be difficult because it is nearly impossible to replicate the original conditions under which data were collected or to control all the variables that might possibly affect findings. That is the 'difference between undertaking research in a laboratory, where one can to some degree "control" variables and conducting it out in the "real" world, where events and happenings follow a natural course' (Strauss and Corbin, 1998).

2.2.1.4 Main Differences between Quantitative and Qualitative Research

The strengths and weaknesses of quantitative and qualitative research are 'a perennial, hot debate, especially in the social sciences' (Neill, 2007). Traditional quantitative researchers, who are concerned with complex human phenomena, 'need to select a sample at random from the whole population or from satisfactory sub-samples of the population' (Remenyi et al, 1991). However, they 'rarely have the opportunity to select a truly random sample and often settle for approximations of randomness' (Maykut and Morehouse, 1994). Qualitative researchers set out to build a sample that 'includes people (or settings) selected with a different goal in mind: gaining deep understanding of some phenomenon experienced by a carefully selected group of people' (Maykut and Morehouse, 1994). The main differences between quantitative and qualitative research methods are identified by the facts that:

- Crucial elements of sociological theory are often best found with a qualitative method;
- Qualitative research is, more often than not, the end product of research; and
- Qualitative research is often the most "adequate" and "efficient" way to obtain the type of information required and to contend with the difficulties of an empirical situation (Glaser and Strauss, 1967).

Both quantitative and qualitative approaches use a series of techniques. Each one of them contains choices and decisions concerning the usefulness of various alternative procedures, whether these are quantitative or qualitative. However, 'the most important consideration for a researcher when making choices is which quantitative and which qualitative ones would be more appropriate for the particular research problem' (Strauss and Corbin, 1998). Table 2.1 highlights the main differences between quantitative and qualitative research.

Table 2.1: Features of Quantitative and Qualitative Research (source: Neill, 2007)

Quantitative Research	Qualitative Research
'There's no such thing as qualitative data. Everything is either 1 or 0' (Fred Kerlinger)	'All research ultimately has a qualitative grounding' (Donald Campbell)
The aim is to classify features, count them, and construct statistical models in an attempt to explain what is observed.	The aim is a complete, detailed description.
Researcher knows clearly in advance what he/she is looking for.	Researcher may only know roughly in advance what he/she is looking for.
Recommended during latter phases of research projects.	Recommended during earlier phases of research projects.
All aspects of the study are carefully designed before data is collected.	The design emerges as the study unfolds.
Researcher uses tools, such as questionnaires or equipment to collect numerical data.	Researcher is the data gathering instrument.
Data is in the form of numbers and statistics.	Data is in the form of words, pictures or objects.
Objective – seeks precise measurement and analysis of target concepts, e.g., uses surveys, questionnaires etc.	Subjective - individuals' interpretation of events is important,e.g., uses participant observation, in-depth interviews etc.
Quantitative data is more efficient, able to test hypotheses, but may miss contextual detail.	Qualitative data is more "rich", time consuming, and less able to be generalised.
Researcher tends to remain objectively separated from the subject matter.	Researcher tends to become subjectively immersed in the subject matter.

Although most researchers apply either the quantitative or the qualitative approach to their research work, some researchers (Ragin, 1987; Lee, 1991; Kaplan and Duchon, 1988; Lee, 1991; Gable, 1994; Markus, 1994; and Mingers, 1995) have suggested the combination of one or more research methods in one study. However, the motivation for undertaking qualitative research, as opposed to quantitative research, comes from the observation that qualitative research methods are designed to help researchers understand people and the social and cultural contexts within which they live. Kaplan and Maxwell (1994) point out that 'the goal of understanding a phenomenon from the point of view of the participants and its particular social and institutional context is largely lost when textual data are quantified'.

2.3 The Area of Investigation within the Context of Information Systems (IS) Research

Research in the field of emergency response management could be categorised under both the social research and the information systems (IS) research areas. This is because during emergencies there is social instability, which needs to be managed and the ways to manage it include both human interaction and IS support at the same time. However, as stated in Chapter 1, the aim of this research work is to "study the feasibility and applicability of Grid technology to emergency management such that stakeholders can monitor, plan, control and manage actions within an emergency situation caused by natural disasters in a more informed way". The focus of the research work and the establishment of this aim are based on preliminary research findings and suggestions from international bodies responsible for emergency response management pointing out the problems in emergency response IS and the need to address these ICT related problems so as to improve effectiveness and efficiency in practice.

Among others, the National Earthquake Hazards Reduction (NEHRP) plan issued by the United States Department of the Interior (2003) makes it clear that hazards and disaster informatics is an essential planning consideration. The National Research Council (2006) supports this, pointing out that 'hazards and disaster informatics is an enormously significant problem'. Therefore, the social implications and problems during emergency response management are considered beyond the scope of this research work, as it is focused on the IS implications and problems the emergency management stakeholders face during response operations to natural disasters.

In order for the aim of the study to be achieved specific objectives have been identified and these, need to be pursued using an appropriate research methodology.

However, the methodology needs to allow the investigation of the problem within IS, but with particular focus on the human activity, as the organisation of emergency response management and the execution of tasks during the response operations are based on human initiative and involvement. Therefore, there is the need for a human-centred methodology to be applied, in order for concerns, such as control, planning, coordination, communication, organisation, human reaction and ultimately, improvement of decision making to be investigated, and at the same time, to have the ability to apply technological solutions, as tools, to support a human-based operation/activity, such as emergency response management.

Remenyi and Williams (1995) classify research methodologies into three categories. These include passive observation (category 1), uncontrolled interventions (category 2) and deliberate intervention (category 3). Category 1 research is suitable for macro problems, while category 3 research is more appropriate for micro problems. Category 2 fits between these two extremes. The most general of the three is the Category 1. This approach is used in research where there may not be a prior theory and therefore the researcher may have to develop a grounded theory by induction of *a priori* observations. This approach is clearly not suitable for tackling the research problem of the study, as findings and everyday practice in the field of emergency management indicate that theory already exists and there is not the need for development of grounded theory. This output leads to category 2 research, which begins with an already established theory, which will be tested by observing the effects of the uncontrolled intervention. This approach could be used for this study as its aim includes the improvement of practice, meaning that there is the need for observing current practice, identifying problems and proposing potential solutions.

Finally, category 3 research (deliberate intervention), focuses closely on a particular aspect of the problem and provides the most detailed information. It relies on having an established theory, as the basis from which the hypotheses may be deduced and which will determine the nature of the intervention. However, this approach does not seem suitable for the area of investigation of this research work, as it is not focused on a particular micro problem within the process, but with the whole process of emergency response management.

Overall, studying the consequences of uncontrolled observations seems to be the most appropriate approach to adopt to address the particular research problem of this study. This is because there is an established theory and/or an operational framework in practice in emergency response management and there is space for observing the effects of the uncontrolled interventions, with particular reference to the IS used during response operations, identifying the problem area and proposing potential solutions to improve the situation. However, there is still the need for the identification of a methodology belonging to category 2, in order for this to be adopted for the benefit of the study. Therefore, the following section is concerned with the research methodologies available to tackle problems within the IS area and identifies why and how Soft Systems Methodology (SSM) can be applied to the research.

2.4 Types of Research Methodologies within IS

The common aim of Information Systems Development Methodologies (ISDMs) is to assist in successfully implementing information systems (Savage and Mingers, 1996). However, several reasons have been noted by Lucas (1975) for the failure of ISDMs to deliver what is required. Many of these failures ultimately occur as a result of limitations in conventional (or "hard") ISDMs (Mingers, 1995). Conventional or "hard" ISDMs deal with well defined problems in real world situations (Horton, 1999). The term "hard" is not used in the sense of difficult, but more in the sense of concrete, or precise. In this way of thinking it is assumed that the system has a goal, that the problems are easily identifiable and that the requirements are largely known. Therefore, all that is needed is for someone to test a series of techniques in order to create the system. However, Lejk and Deeks (2002) point out that it is not always clear what are the problems, that sometimes everyone recognises that there is a problem, but there is a lack of consensus as to what it is and finally, that sometimes there is a general sense that things need improving but no one knows what or how. Galliers (1987) further points out that these ISDMs lack mechanisms or techniques for identifying the key information requirements of the user, as ISDMs assume that existing systems are effective or that users know what they want and their requirements lead straightforwardly to a technical solution. It is argued that, as these methods pay less attention to the human aspects compared to the technical aspects (Galliers, 1987) and hard methodologies are geared primarily towards the technological aspects of design, this causes a concentration on technical solutions to what may be complex social, organisational and communicational problems (Mingers, 1995).

In addition to the above, Hirschheim and Klein (1989) state that "hard" methodologies are underpinned by a positivist or objectivist viewpoint, while other researchers, such as Boland (1985), Miles (1988), Lyytinen and Klein (1985), Winograd and Flores (1987), Checkland and Scholes (1991), Stowell (1985), Lewis (1993) and Bessis (2002) have argued that this viewpoint is inappropriate for designing information systems, which are but a part of the whole process of human communication. The failure to cope with anything other than well structured problem situations led to the basic rethink of the fundamentals of systems thinking (Checkland and Scholes, 1991). Soft Systems Methodology (SSM) was developed in the 1970s in order to cope with problems that ISDMs were not capable of handling. It is based on the assumption that all the real world problem situations have at least one thing in common: they contain people interested in trying to take purposeful actions. The idea is that a set of activities, which are linked together so that the whole set, as a new entity, could pursue a purpose, was taken to be a new kind of system concept, called a human activity system (Checkland and Holwell, 1998). This was to alleviate the main weaknesses of the ISDMs, which is that they try to extract a single set of compatible user requirements rather than to explore, and understand users' requirements within a problem situation (Wood and Doyle, 1989).

The initial aim of SSM is to generate a rich understanding of the relevant situation before exploring potential improvements. It is an organised way of tackling messy situations in the real world (Checkland and Scholes, 1991). In contrast to hard systems, SSM constructs conceptual models of systems and uses them as tools for investigating the real world (Horton, 1999). It enables someone to view a collection of interrelated items as an ordered arrangement, which as a whole achieves some purpose (Patching, 1995). As opposed to hard systems, SSM addresses complex, badly structured problem situations. It is concerned with investigating a problematic situation that is not well defined.

Table 2.2: Hard versus Soft Traditions (source: Checkland and Holwell, 1998)

	The 'Hard' Tradition (Simon)	**The 'Soft' Tradition (Vickers)**
Concept of organisation	Social entities which are set up and seek to achieve goals	Social entities which seek to manage relationships
Concept of information system	An aid to decision making in pursuit of goals	A way of interpreting the world, and make sense of it, in relation to managing relationships
Underlying systems thinking	'Hard' systems thinking: the world assumed to be systemic	'Soft' systems thinking: the process of inquiry into the world assumed to be capable of being organised as a system
Process of research and inquiry	Predicated upon hypothesis testing: quantitative if possible	Predicated upon gaining insight and understanding: qualitative
Social theory	Functionalism (stemming from Durkheim)	Interpretive (stemming from Weber)
Philosophy	Positivism	Phenomenology

Table 2.2 illustrates the differences between the "hard" and "soft" methodologies in terms of the concepts of the organisation and information system under investigation, the underlying systems thinking, in terms of the process of the research inquiry, the social theory and the philosophy of the approach. In particular, the "hard" tradition is used for organisations that stand as social entities, which are set up and seek to achieve specific goals, with the aid of information systems as decision making tools to pursue this goal. This approach assumes that the world is systemic and uses quantitative methods to create, analyse and evaluate data. The social theory is

reflected in functionalism and the philosophy of this approach is positivism. In contrast, the "soft" approach is used for organisations that stand as social entities that seek to manage relationships and they consider information systems as a way of interpreting the world and making sense of it in relation to managing relationships. The underlying system thinking in these situations is that the process of inquiry into the world assumes it to be capable of being organised as a system. Thus, in such situations the qualitative method is used to tackle the problem area. The social theory of this approach is interpretive and its whole philosophy is the phenomenology. However, researchers adopting either the "hard" or the "soft" approach need a series of methods, as defined in Section 2.2, in order to apply the selected methodology to the area of investigation.

2.5 Suitability of Soft Systems Methodology (SSM) in the Context of the Present Research Study

The present research investigates the field of emergency management for natural disasters, with special reference to the stage of emergency response. In particular, it examines the approaches used by the authorities involved at this stage in order to manage, control and coordinate emergency response operations through the generation of informed decisions of action and their communication to relevant parties. It is thought that SSM can be applied as the appropriate methodology to investigate the situation and to propose appropriate actions to the research problem of the study because of the following:

- The nature of identifying how emergency response decisions and orders of action could be communicated more effectively and efficiently between parties involved is a complex process, which is not well defined;
- The research is concerned with a messy situation, and therefore it could not be handled with a straightforward, linear and organised solution, such as a "hard" approach;
- The present research does not aim to focus only on the technological aspects, as it is also concerned with the human aspects (Asimakopoulou et al, 2005) as

emergency response operations have both human and technological dimensions.

Based on the above, it is thought that the field of emergency response management should be approached with a soft methodology, using qualitative methods to investigate the situation. Hence, SSM, along with its methods mainly is applied to the present research work to explore the area of interest, to identify any potential problems during emergency response operations, with particular interest in the communication between stakeholders and the proposal of conceptual solutions. Overall, the reasons for adopting SSM are:

- The fact that there is no existing systems for emergency response management to compare with any potential proposal;
- The nature of identifying how emergency response decisions and orders could be communicated more effectively and efficiently between relief units;
- This research is concerned with a messy situation, therefore it could not be handled with a straightforward, linear and organised solution;
- The present research does not aim to focus only on the technological aspects, as it is concerned with the human aspects as well.

The next Section presents a detailed review of SSM.

2.6 The SSM

According to Professor Peter Checkland, the originator of Soft Systems Methodology (SSM), SSM is not a method for solving problems. It is a methodology (the originator defines methodology as 'a set of principles of methods') able to provide a way of investigating problematic situations and suggesting action to be taken. SSM was originally described as a seven stage process (Checkland, 1975) and these are illustrated in Figure 2.1.

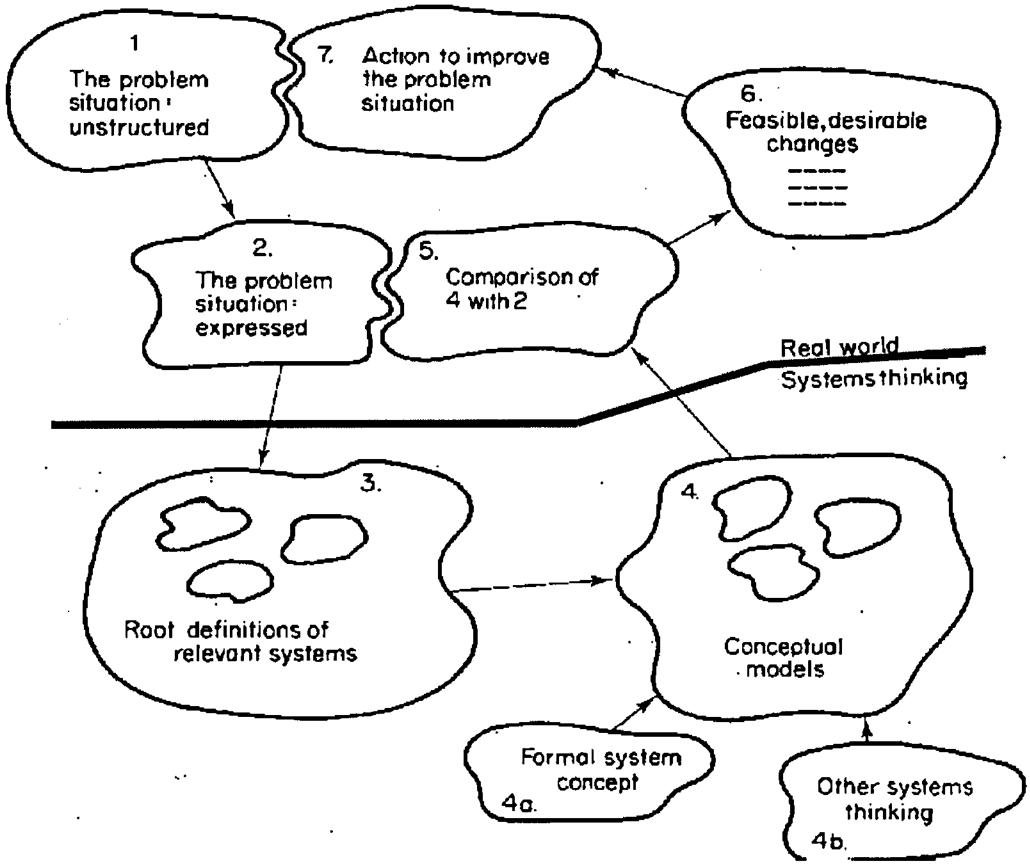


Figure 2.1: The Conventional Seven Stage Process of SSM as in 1975 (source: Checkland and Scholes, 1991)

However, 'it was felt in the late 1980s that the 1975 version seems rather bald, and in any case creates too much of an impression that SSM is a seven-stage process to be followed in sequence' (Checkland and Scholes, 1991). In response, SSM has been further developed and the seven-stage process has become outdated. The new form of SSM is more sophisticated and consists of 'two parallel streams of activity which interact with each other' (Horton, 1999).

This major step forward enables the 'judgement of cultural analysis to be made in terms of the intervention itself; the social system of the problematic situation; and its politics' (Checkland, 1995). These result in 'a better representation of SSM' (Checkland and Scholes, 1999).

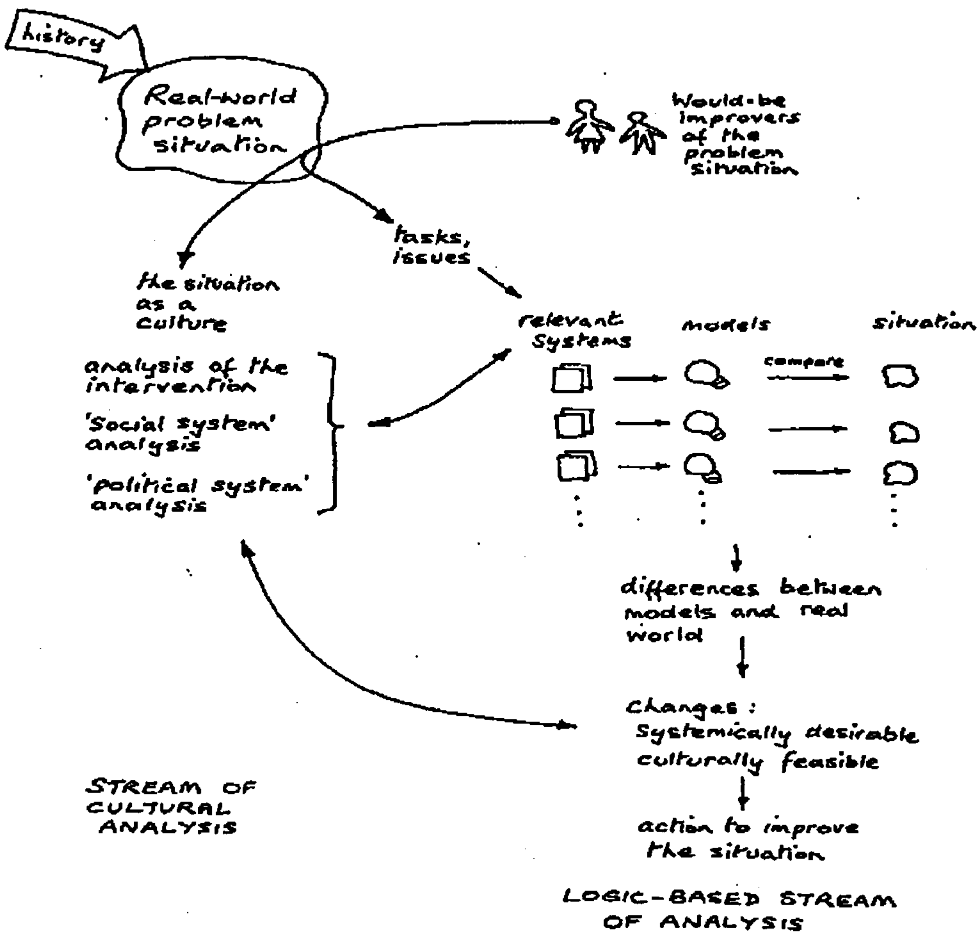


Figure 2.2: The Process of SSM, 1988 (source: Checkland and Scholes, 1999)

This process is shown in Figure 2.2 and is the version which has been used in this research. The concept of the present version is described by von Bulow (1989) as 'a methodology that aims to bring about improvement in areas of social concern by activating in the people involved in the situation a learning cycle which is ideally never-ending'. The learning takes place through the interactive process of using systems concepts to reflect upon and debate perceptions of the real world, taking action in the real world, and again reflecting on the happenings using systems concepts. The reflection and debate are structured by a number of systemic models. These are conceived as holistic ideal types of certain aspects of the problematic situation rather than as accounts of it. It is taken as given that no objective and complete account of a problem situation can be provided.

Table 2.3: SSM's Epistemology (source: Checkland and Scholes, 1999)

Real World	The unfolding interacting flux of events and ideas experienced as everyday life
Systems Thinking World	The world in which conscious reflection on the 'real world' using systems ideas take place
Problem Situation	A real-world situation in which there is a sense of unease, a feeling that things could be better than they are, or some perceived problem requiring attention
Analysis One, Two, Three	Analysis One: examination of the intervention or interaction in terms of the roles; 'client' (caused the study to take place), 'problem solver' (undertakes the enquiry) and 'problem owner' (plausible roles from which the situation can be viewed, chosen by the 'problem solver') Analysis Two: examination of the social (cultural) characteristics of the problem situation via interacting roles (social positions), norms (expected behaviour in roles) and values (by which role-holders are judged) Analysis Three: examination of the power-related (political) aspects of the problem situation via elucidation of the 'commodities' of power in the situation
Rich Picture	Pictorial / Diagrammatic representations of the situation's entities (structures), processes, relationships and issues
Root Definitions	Concise verbal definitions expressing the nature of purposeful activity systems regarded as relevant to exploring the problem situation. A full Root Definition would take the form: do X by Y in order to achieve Z
CATWOE	Elements considered in formulating root definitions. The core is expressed in T (transformation of some entity into a changed form of that entity) according to a declared *Weltanschauung (Worldview),* W. C (customers) victims or beneficiaries of T. A (actors): those who carry out the activities. O (owner): the person or group who could abolish the system. E: (the environmental constrains which the system takes as given)
The 5Es	Criteria by which T would be judged: Efficacy (does the means work?); Efficiency (are minimum resources used?); Effectiveness (does the T help the attainment of longer term goals related to O's expectations?); Ethicality (is T a moral thing to do?); Elegance (is T aesthetically pleasing?)
Conceptual Model	The structured set of activities necessary to realise the root definition and CATWOE, consisting of an operational subsystem and a monitoring and control subsystem based on the Es
Comparison	Setting the conceptual models again the perceived real world in order to generate debate about perceptions of it and changes to it which would be regarded as beneficial
Desirable/Feasible Changes	Possible changes which are (systematically) desirable on the basis of the learned relevance of the relevant systems, and (culturally) feasible for the people in the situation at this time
Action	Real-world action (as opposed to activity in conceptual models) to improve the problem situation as a result of operation of the learning cycle for which this epistemology provides a language

Table 2.3 presents the SSM epistemology as the language which is used during the process described above and the language which has been applied in this study.

The following sub-sections present a more detailed background review that aims to demonstrate both the streams of the logic-based enquiry and the cultural-based analysis of the SSM and also to explain common SSM terminology. It is worth noting that these streams interact with each other and they proceed in parallel. The following sub-sections are based on the following works: Checkland (1981), Checkland and Scholes (1991), Mingers (1995), Patching (1995), Checkland and Holwell (1998), Horton (1999), Checkland and Scholes (1999) and Skidmore and Eva (2004).

2.6.1 The Stream of Logic – Based Enquiry

The stream of logic-based enquiry is a stream of thinking and discussion, which is essentially logic-driven and can be used to question the real world. It is concerned with the naming and modelling of a number of human systems describing their purposeful activities in the form of models. It is used to illuminate the problem situation. The approaches required to fulfil this are as follows:

- Selecting Relevant (Conceptual) Systems;
- Naming Relevant Systems – Root Definitions and CATWOE;
- Modelling (Conceptual) Relevant Systems;
- Comparing the Model with Perceived Reality.

2.6.1.1 Selecting Relevant (Conceptual) Systems

This step is used in order to identify and describe relevant conceptual systems that do not exist in the real world. These systems are examined in relation to the different views and beliefs that exist within a specific situation. These views are known as "Weltanschauung" (worldviews). Worldviews refer to the problem themes and they are known as primary task relevant systems, while the issues in the problem situation are known as issue-based relevant systems.

2.6.1.2 Naming Relevant Systems – Root Definitions and CATWOE

Some of the relevant systems identified above are further defined and modelled in this step. The root definition expresses the core purpose of the system. This input - output conversion is known as the transformation (T). The root definitions may be formulated as follows: who is doing what for whom, to whom are they answerable, what assumptions are being made, and in what environment. This is also known as 'the CATWOE mnemonic' (Smyth and Checkland, 1976) and its explanation is:

- **Customers (whom):** beneficiaries or victims of the transformation (T);
- **Actors (who):** those who would do the transformation (T);
- **Transformation (what):** the conversion of input to output;
- **Weltanschauung (assumptions):** those worldviews which make this T meaningful within its context;
- **Owner(s) (answerable):** those who own the system and often have the authority to stop the T;
- **Environmental Constraints:** elements outside the system, e.g. physical, social.

'Each root definition takes a view of what the system should be achieving, through the transformation (T) and the Worldview (W). The next step is to explore what should happen in the system in order for this to be achieved' (Skidmore and Eva, 2004). The model used for this is called the conceptual model and it is presented next.

2.6.1.3 Modelling Relevant (Conceptual) Systems

The conceptual model 'shows the activities needed to make the root definition a reality' (Skidmore and Eva, 2004). That is to say, the system is modelled in terms of activities expressed as verbs. This model contains the activities necessary to carry out the transformation (T) within other constraints of the model. However, the system as a whole entity should adapt and survive in the changing environment of the complexity of everyday life. Forbes and Checkland (1987) highlighted three criteria by which the performance of a proposed system as a whole is judged. These are known as the "3Es" and they are as follows:

- **Efficacy:** "does the mean work?", this checks of whether the output is of working order;
- **Efficiency:** the "amount of output divided by the amount of resources used", which checks whether minimum resources are used to obtain it;
- **Effectiveness:** "is T meeting the longer term aim?", this checks whether this T is worth doing.

Although the "3Es" cover the most basic idea of transformation, 'current considerations include additional an two Es, which represent the criteria of Ethicality and Elegance' (Checkland and Scholes, 1999).

2.6.1.4 Comparing the Model with Perceived Reality

This step is related to the evaluation of the created conceptual model. The comparison of the conceptual model with perceived reality involves examination and identification of its activities in terms of:

- Whether they exist or not in real world situation;
- In what form they exist in real world;
- In what systems they exist in real world;
- Whether the activities that exist in real world are good or bad.

Checkland (1991) presents four ways of evaluating models, and these are:

- informal discussion;
- formal questioning;
- scenario writing based on operating the models;
- trying to model the real world in the same structure as the conceptual models in which formal questioning has emerged as by far the most common technique (Checkland and Scholes, 1991).

2.6.2 The Stream of Cultural Enquiry

As the logic-based stream of enquiry has a part to play in human affairs, there is also a need to pay attention to other aspects of human situations, which specifically make these affairs human. Therefore, this stream involves the myths and meanings which human beings attribute to their professional and personal relationships with their fellow beings. Based on these, the following ways of enquiring into the systems of myths and meanings, which constitute what is meant by culture, are described as:

- Rich Pictures;
- Analysis One: Analysis of the Intervention;
- Analysis Two: Social Systems Analysis;
- Analysis Three: Political Systems Analysis;
- Making Desirable and Feasible Changes.

These are further discussed bellow.

2.6.2.1 Rich Pictures

'Rich Pictures are a form of drawing to visualise the problem domain' (Skidmore and Eva, 2004). It is a technique which has been used to explore the communication and comprehension of the problem situation. Checkland and Scholes (1999) stated that 'the rationale of the Rich Pictures lies in the fact that the complexity of human affairs is always a complexity of multiple interacting relationships and therefore, pictures are considered a better medium than linear prose for expressing relationships'. Rich Pictures 'can be drawn either by the problem solvers or by the actors themselves for their own part of the system' (Skidmore and Eva, 2004). Rich Pictures are used to demonstrate the following:

- **Structure:** organisation or field boundaries, geographical considerations, people and institutions;
- **Process:** activities, flows of information or materials;
- **Climate:** the relationship between structure and process and any associated problems;

- **Soft facts:** concerns, conflicts and views;
- **Environment:** external interested bodies, factors affecting organisation or field (Checkland and Scholes, 1999).

'Rich pictures focus as much on the human activity system as on the more formal function/processing aspect of the environment. That is what gives them their richness' (Skidmore and Eva, 2004). The way they will be used depends upon the problem solvers.

2.6.2.2 Analysis One: Analysis of the Intervention

Analysis One is the analysis of the intervention and it refers to the problem solving activity and the SSM study itself. It also determines who occupies the three specific roles in the intervention. These roles are the:

- **Client:** the person who commissions or who caused the study to take place;
- **Problem solver(s):** those who wish to do something about the situation, or those who are prepared to support the study by making resources available;
- **Problem owner(s):** this lists the possible problem owners and always includes the client.

2.6.2.3 Analysis Two: Social Systems Analysis

Analysis Two refers to the social system in the problem area, which consists of a continually changing interaction between roles, norms and values; in particular,

- **Roles:** these are social positions which are recognised by people in the situation under study;
- **Norms:** these are the ways in which the occupant of a particular role is expected to behave;
- **Values:** these are the standards on which performance of role holders is assessed.

2.6.2.4 Analysis Three: Political Systems Analysis

Analysis Three, the political systems analysis, is focused on the way in which power is gained, maintained and used. It is concerned with the process by which different interests reach accommodation that does not necessarily involve agreement. Analysis Three is further concerned with the fact that everyone who participates in a group quickly acquires a sense of what they should do to cause things to happen, to stop possible actions and to significantly affect the actions which the group takes. 'The means, in which the power is embodied, are called "commodities"' (Checkland and Scholes, 1999).

2.6.2.5 Making Desirable and Feasible Changes

Checkland and Scholes (1999) argued that SSM 'aims to do something about a situation regarded as, in some way, unsatisfactory'. As action has been applied using SSM, these changes are aimed at helping to remove the dissatisfaction. These changes themselves are usually described as "systemically desirable" and "culturally feasible".

2.6.3 The Benefits of SSM

In contrast to hard systems, SSM 'constructs conceptual models of systems and uses them as tools for investigating the real world' (Horton, 1999). It enables someone 'to view a collection of interrelated items as an ordered arrangement which, as a whole, achieves some purpose' (Patching, 1995). Also, as opposed to the hard systems, SSM addresses complex, badly structured problem situations. It is concerned with the investigation of a problematic situation that is not well defined. Many authors including Checkland and Scholes (1999), Bessis (2003) and Cushman and Venters (2004) have used SSM to appreciate human interaction as an interrelated item within an activity system.

2.6.4 The Limitations of SSM

Although SSM activity models can form a cogent basis for information flow models upon which the information system design process can be based (Checkland and Griffin, 1970), there is no systematic way of determining the information needed and produced by an activity, nor of developing data models. In other words, 'there is no connection to standard IS design methodologies or case tools to facilitate the detailed design work after the requirements have been identified' (Mingers, 1995). However, Checkland and Scholes (1991) have stated that 'SSM subsumes the hard approach, which is a special case of it; one which arises when there is local agreement on some system to be engineered'. To this extent, many researchers have tried to link SSM with other existing structured design methods. This was first raised by Stowell (1985) who suggested that 'an agreed conceptual model could be expanded into a detailed data specification using process or data flow diagrams'.

In trying to establish links between SSM and ISDMs, three different options have been suggested by Wood and Doyle (1989): firstly, by incorporating tools and techniques from ISDMs within an SSM framework; secondly, by linking SSM to ISDMs, where SSM is used as a front-end and thirdly, by using elements of both methodologies to build a framework. Miles (1988) has named the first two options as "embedding" and "grafting" respectively. In linking SSM with other ISDMs, Mingers (1995) referred to a number of different approaches that have been studied, including Miles, 1988; Prior, 1990; Avison and Wood-Harper, 1990; 1992; Sawyer, 1991; Grecory and Merali, 1992; and Savage and Mingers, 1996. The next section stands as a presentation of the SSM's methods, techniques and tools used throughout the research.

2.7 The Methods, Techniques and Tools used throughout the Study

The methods of SSM, as presented in Section 2.6, were employed throughout the research study and presented in this thesis. In particular, once the literature review has briefly identified the area of investigation in Chapter 3, the case study technique has been employed in Chapter 4. This technique has been chosen in order for the investigation to be focused on a specific number of samples, as the literature review has revealed that this approach is widely adopted and used by the particular community in focus. In addition to this, the complex nature of the research area under investigation leads to the use of case studies as it is considered as the technique that supports 'the understanding of a complex issue or object and can extend experience or add strength to what is already known through previous research' (Soy, 1997). Yin (1984) further defines the case study technique as 'an empirical inquiry that investigates a contemporary phenomenon within its real-life context; when the boundaries between phenomenon and context are not clearly evident; and in which multiple sources of evidence are used'. According to Yin (1994) the case study technique has four stages and these include: the design of the case study, the conduction of the case study, the analysis of the case study evidence and finally, the development of the conclusions, recommendations and implications.

For the purpose of this research, two member states of the European Union have been used as case studies. These are Greece and the UK and in particular the authorities involved in the response phase of emergency management for natural disasters. In order for the exact problems and conflicts in the area to be identified a primary research tool has been formulated and used. In particular, a series of one-to-one structured interviews has been produced and carried out with emergency management stakeholders in the two countries for the most accurate identification of the problem. Findings from both structured interviews and literature review have been discussed, presented and analysed through a Rich Picture. They have been further analysed using the methods of SSM including Analysis One (Analysis of the Intervention); Analysis Two (Social Systems Analysis) and Analysis Three (Political Systems Analysis). Following this process, the Selecting Relevant (Conceptual) Systems process took place in order for the human activity to be named in relation to the problem situation and to focus on the issues, problems and conflicts within the problem situation.

The next step of the SSM epistemology has been followed in Chapter 5, which is the Naming of Relevant Systems through the establishment of the Root Definition and CATWOE. These aim to further inform the process towards the formulation of the proposed solution in the form of a conceptual model, which aims to improve the control, planning, coordination, decision making and communication between relevant stakeholders involved in emergency response management. Based on these the Modelling (Conceptual) Relevant System process followed and the description of its activities is achieved through the use of a case scenario. Finally, Chapter 5 compares the proposed Model with Perceived Reality, discusses findings and identifies potential and feasible changes for the real world.

As the main aim of the study is to study the feasibility and applicability of Grid technology to emergency management such that stakeholders can monitor, plan, control and manage actions within an emergency situation caused by natural disasters in a more informed way, literature review is used in Chapter 6 to investigate Grid technologies. Further to this, a primary research tool – one-to-one structured interviews – has been employed and carried out with Grid technology experts to fully inform findings. Its aim was to discuss and evaluate the opportunities for using Grid technology within emergency response management prior to the development of an appropriate conceptual Grid-Aware Emergency Response Model (G-AERM). Chapter 7 incorporated the findings from the Chapter 6, along with guidelines used for producing real world technical requirements, to produce a relevant process flow chart, an outline conceptual G-AERM and ultimately, the set of both real world and Grid-based technical requirements for the G-AERM's architecture. The linking together SSM with ISDMs as the front-end was employed in order to produce the aforementioned set of guidelines and G-AERM architecture.

Further to these, Chapter 8 is concerned with the evaluation of the proposed solution in both conceptual and technological terms. SSM's epistemology suggests that the evaluation of the proposed solution has to be undertaken in terms of the three Es – effectiveness, efficiency and efficacy. However, as the focus of this research work was not to create a real world manifestation, but to propose the concept and the most appropriate technology for a single model to accommodate the activities of emergency response operations, the evaluation was conducted in terms of effectiveness and efficiency only, whereas efficacy is related to whether the real-world application is working or not. Therefore, the activities conducted included the evaluation in relation to the SSM conceptual Emergency Response Model (ERM) and the evaluation in relation to the Grid-based technical requirements for the G-AERM. For these tasks to be carried out two evaluation tools have been formulated.

These are two sets of structured interview questions, which have been conducted on a one-to-one basis, in order for both perspectives to be addressed. The first interview exercise was held with the emergency management stakeholders representing the two counties used as case studies, and the second one with the group of Grid technology experts. The findings from the evaluation exercises have been analysed and critically discussed in Chapter 8 of the thesis. Findings have been analysed and presented with the use of SWOT analysis. The SWOT acronym stands for Strengths, Weaknesses, Opportunities and Threats. These refer to a project or an organisation. SWOT analysis is usually used to assess an organisation's performance or a proposed project or a new strategy. In particular, SWOT analysis assesses a project's strengths – what the project can do – and weaknesses – what the project cannot do – in addition to opportunities – potential favourable conditions for the project – and threats – potential unfavourable conditions for the project. According to Danca (2007) SWOT analysis is an important tool for planning. The role of SWOT analysis is to take the information from the environmental analysis and separate it into internal issues (strengths and weaknesses) and external issues (opportunities and threats). Once this is completed, SWOT analysis determines if the information indicates something that will assist the owners of the project in accomplishing its objectives (a strength or opportunity), or if it indicates an obstacle that must be overcome or minimised to achieve desired results (weakness or threat) (Ferrell et al, 1998).

In the context of this research the components of SWOT analysis are based on the one-to-one interview exercises and it is used to appreciate the strengths of the G-AERM, define its weaknesses, demonstrate how the relevant community can make the most of the related opportunities that the G-AERM offers and finally, recognise possible threats. Overall, this approach helps to evaluate the proposed G-AERM and further to this it stands as a guideline for the users of G-AERM's real world application as they can make the most of the opportunities it offers and they can recognise the possible threats and treat them in a planned and organised way. In addition to this, SWOT analysis of the G-AERM identifies room for further work as based on the appreciation of the strengths someone may decide to build on these or minimise its weaknesses.

In conclusion, SSM has been employed as the most relevant methodology to tackle the problem area throughout the research. A series of methods have been used in order SSM epistemology to be followed. In particular, literature review has been used to gain a better understanding about natural disasters, emergency management, and Grid technology. Case studies have informed the study with ways of current practice of emergency response operations. Based on them, one-to-one structured interview have been created and conducted with relevant stakeholders in order current ICT limitations to be further identified. Structured interviews have also been used to assess the feasibility and applicability of Grid technology to the problem area. Modelling techniques have resulted to the ERM and G-AERM, which has been evaluated using one-to-one structured interview exercises. Findings have been analysed and discussed via the use of SWOT analysis. Table 2.4 summarises the methods used throughout the research study under the SSM epistemology.

Table 2.4: Research Methods Used throughout the Study

SSM	Research Methods	Used in Chepter:	Quanitative	Qualitative	Related to Objective:	Led:
The selected research methods follow SSM epistemology	Literature Review	2,3,4,6		√	1,2,3	Identification of natural disasters and emergency management / Identification of emergency management processes / Identification of the authorities involved / Examination of Grid technology
	Case Studies	4		√	2	Identification of current processes of emergency response management / Identification of ICT in use / Identification of limitations
	Structured Interviews	4,6,8		√	2,3,5	Identification of ICT limitations / Validation of Grid as appropriate technology for the ERM / Evaluation of the G-AERM
	Modelling Techniques	5,7		√	4	ERM / G-AERM
	SWOT Analysis	8		√	5	Evaluation of G-AERM concept and architecture / Identification and presentation of findings

2.8 Summary

Chapter 2 has been concerned with the presentation of the available research methodologies along with their methods and techniques pointing out their main differences. In particular, the "hard" and "soft" approaches and the quantitative and qualitative methods have been discussed. The Chapter concluded that the "soft" approach is considered the most appropriate one for the exploration, identification and demonstration of the conflicts and problems (front-end), which emergency management stakeholders face during the decision making and action process of the response operations to natural catastrophic events. This Chapter has also presented a review of SSM, as the methodology employed in the present research study. Further to this, it has been considered as important to highlight the advantages of SSM in relation to other methodologies, as it is the methodology concerned with areas of social concern. It investigates the research problem with the main focus on the human multi-perspective views, and overall, it is considered an appropriate methodology to address messy problematic environments. SSM along with the linking of SSM with ISDMs methods have been applied in this research study in order for the feasibility and applicability of Grid technologies in emergency response management to be explored. Further to this, they assist in the formulation and evaluation of a Grid-aware conceptual model that will allow emergency management stakeholders to monitor, plan, control and manage actions within emergency situations caused by natural disasters.

The next chapter presents a literature-based review of natural catastrophic phenomena, their consequences in human organised societies and emergency management as the discipline responsible for overcoming these implications and minimising losses in human lives, property and the environment. Finally, it highlights the constraints of managing emergency situations caused by the occurrence of such natural catastrophic phenomena.

Chapter 3 Natural Disasters and Emergency Management

3.1 Introduction

The discussion in the previous chapter indicates that Soft Systems Methodology (SSM) is the most appropriate methodology to tackle the issues being addressed in this research. In order for this to take place; there is the need for detailed examination of the key terms involved in the area of investigation. On this basis, Chapter 3 is concerned with the identification of key terms and the establishment of definitions related to them. In particular, the next sections, based on literature review, present various definitions concerned with natural phenomena and the catastrophes that they may cause. They also discuss how these phenomena may be characterised as emergencies or disasters, through understanding of these terms and the examination of their implications for the human society. People attempt to manage these disastrous situations through the establishment of emergency management as the discipline responsible. In addition to this, the following sections are concerned with examining the different phases of emergency management during an emergency's life cycle. The chapter also provides a brief presentation of some of the leading international bodies and organisations working on aspects of emergency management in avoiding or mitigating the adverse impacts of natural catastrophic phenomena. It concludes with constraints related to the management of natural disasters, in relation to their highly demanding nature.

3.2 Definition of Key Terms

As the scope of this chapter is to study natural phenomena, natural disasters and emergency management it is considered useful first to define the key terms and this is the focus of this section.

The term "nature", as created and understood by people, could be considered as 'a casual agent creating and controlling things in the universe' (worldreference, 2006). It includes all the animals, plants, rocks, etc. in the world and all the features, forces and processes that happen or exist independently of people, such as the weather, the sea, mountains, reproduction and growth (Cambridge Dictionary, 2004; worldreference, 2006). The involvement of these variables points out that the term "natural" should be considered as something which is present in, or produced by nature. The term "nature" is also referred to as the 'material world and its phenomena' (Dictionary.com, 2004). A phenomenon is characterised as 'something that exists and can be seen, felt, tasted, etc., especially something, which is unusual or interesting' (Cambridge Dictionary, 2004). This leads some to argue that most of the things that happen in the universe, independently of people's plans or actions could be characterised as phenomena.

Overall, phenomena such as earthquakes, hurricanes, storms, landslides and others are present in or produced by nature and therefore, these should be considered as natural phenomena. These types of natural phenomena take place daily around the planet and are considered as usual and essential for human life and environment. This is also supported by Abramovitz (1999) who points out that 'floods, storms and other events are a vital part of nature, restoring soil fertility and shaping the landscape'.

On this basis, 'natural phenomena shall be considered as normal and essential planetary actions' (Asimakopoulou et al, 2005). 'Natural hazards are naturally-occurring physical phenomena caused either by rapid or slow onset events having atmospheric, geologic and hydrologic origins on solar, global, regional, national and local scales' (Unesco, 2006) when they appear in some extreme forms they may cause large-scale changes into the shape and anatomy of the earth. This is evident as 'natural phenomena have periodically decimated the population of the planet' (Mitra, 2001). It is therefore clear that an extreme natural phenomenon may be characterised as catastrophic and hazardous by the scope of people in relation to their lives, property, as well as their environment. This is because natural disasters are not entirely considered as "natural", 'as people may be considered as agents of disasters' (Unesco, 2006). This is also supported by Papanikolaou (2000) who points out that consequence of extreme natural phenomena 'depends on the existence or not in the area of affect of human societies and on the general level of civilisation and technological advantages'. In particular, various sources

(Assar, 1971; Lekkas, 2000; UN, 1992; 2003; NRC, 2006) report that a catastrophic natural phenomenon involves loss of, or damage to, human and animal lives, disruption of normal activities, spread of communicable diseases, destruction of, or damage to, private and public property, and finally, disruption of community services including electricity, gas and other fuels, communications, water supply, sewerage system, food supply, public health, and others.

However, 'a basic distinction has to be made between extreme events in nature, which are not necessarily hazardous to people, and the character of hazardous events' (Burton et al, 1978). Natural phenomena may occur in extreme forms without affecting human organised societies, such as heavy snow and low temperatures at the poles. However, when extreme snowfalls and very low temperatures affect an inhabited area it causes disruption to the normal procedures of the community. Unesco (2006) states that 'natural disasters are the consequences or effects of natural hazards'. Kreps (2001) further supports this by pointing out that 'disasters are non-routine events in societies or their larger subsystems (regions and communities) that involve conjunctions of physical conditions with social definitions of human harm and social disruption'. The term "hazard" is often referred to as something that is dangerous and likely to cause damage. There are various interpretations of what may be called a hazard. An indicative definition is the one established by the Internationally Agreed Glossary of Basic Terms Related to Disaster Management of the Department of Humanitarian Affairs of the United Nations (UN-DHA, IDNDR). UN-DHA (1992) states that a 'hazard is a threatening event, or the probability of occurrence of a potentially damaging phenomenon within a given period and area'. Cutter (2001) notes that the distinction between hazard, and disaster is important because it illustrates the diversity of perspectives on what we do about environmental threats (hazards), and how we respond to them after they occur (disasters). Therefore, for the scope of this study the term "hazard" is considered as an extreme natural catastrophic phenomenon that causes disastrous results to human organised society. With the same rationale, Lekkas (2000) defines natural catastrophic phenomena in terms of:

- The elements of the natural environment, which are harmful for humans and which are caused by unfamiliar and unknown forces. These events may include earthquakes, tidal waves and other phenomena not well known by science;
- The probability of occurrence of a potentially damaging phenomenon within a given period and area, such as heavy rain or snow, tornadoes and other foreseeable phenomena;
- A natural or human-caused geological situation or phenomenon, which during its occurrence can cause real or potential danger to human life or property. Such events may include earthquakes and landslides.

Given this distinction and in particular with the last point, the question then arises as to what extent people, their civilisation and their actions in general cause and/or assist in the occurrence of natural phenomena. Moreover, are those actions enough to interfere with nature and be held responsible for causing a change in one or more aspects, such as magnitude, timing, or area of occurrence? Some may argue that this might be the case. In particular, Bryant (1991) states that there is a theme, which examines 'human effects upon the earth's environment and is concerned ultimately with the question of whether or not people can irreversibly alter that environment'.

In the recent past, there has been much activity examining human impact on climate, on land use practices on the landscape in prehistoric and recent times, the use of nuclear devices in both war and peace and any other human action on the earth's environment. Through this process scientists try to find out the level of impact of human activities on the planet and in general on the environment which surrounds it. Findings have led researchers into a big debate of whether or not people's actions create the occurrence of extreme phenomena in nature or if these actions maximise the impact of these phenomena. Burton et al (1978) point out that 'large parts of the social system may be regarded as operating independently of natural events. Interaction of the two creates resources. It also creates hazards or negative resources' to humans and their organised processes. However, there is another point of view, which suggests that people are present in and products of nature, and they may be assumed 'as specks of dust moving through time subject to the whims of nature' (Bryant, 1991). This statement may imply that whatever happens in nature is beyond human action; something happens anyway and people simply experience it without contributing to it. This is further supported by the Cambridge Dictionary (2004), which suggests that "natural" is something 'as found in nature and not involving anything made or done by people'.

Although the above-mentioned concerns and the distinction between earth functions and human-caused earth functions are of great interest, they are considered beyond the scope of the present study. For the purpose of this study, natural catastrophic phenomena are considered as given and essential planetary functions supporting the existence of the universe and the natural world, which in some extreme forms may cause catastrophic results and therefore, disasters to human life, property and environment. A detailed categorisation and definition of natural disasters follows.

3.3 Natural Disasters

This section is concerned with the classification of natural disasters according to their type. It also presents and discusses some individual phenomena that humans consider as a threat to their assets.

There are various natural phenomena which, depending on their scale, can be catastrophic and cause disasters and therefore, they may expose people's lives and organised societies to risk. Defined or not, categorised or not, the result of the occurrence of natural catastrophic phenomena is that they affect humans and their organised society. Assar (1971) points out that they are 'acts of nature of such magnitude as to create a catastrophic situation in which the day-to-day patterns of life are suddenly disrupted'. Some of these natural phenomena include: avalanches; cyclones; drought; hot, humid summer days; earthquakes; floods; fog; snow; forest fires; landslides; tidal waves; tornadoes; typhoons; and volcanic eruptions.

Various professional, academic and governmental bodies have recorded these phenomena and their potential catastrophic results. Amongst other things, they try to explore them further in order to understand and control them to some degree. These attempts have their foundations back in the ancient world, when people tried to explain the natural world and its phenomena. According to the knowledge and beliefs of each era different explanations have been given throughout the human epoch. Starting with supernatural beings and forces, such as gods and beasts, people have now reached a greater understanding of these situations through a more scientific approach. Many different disciplines – such as history, geology, meteorology, astrophysics, chemistry, physics, sociology, economics and philosophy – have combined their findings in order to draw conclusions in relation to natural catastrophic phenomena. Scientists and governmental bodies have set a series of values in order to be able to assess, to classify and to examine these natural disasters using a common terminology. These values include the frequency of occurrence and the magnitude of the phenomenon, its nature, the location affected, the development of its dynamics, and finally the impact of the event (EU, 1999; Lekkas, 2000).

The categorisation of natural disasters is considered an extremely difficult task since they are characterised as highly complex phenomena. There are different ways that scientists have used to categorise natural catastrophic phenomena. They can be categorised according to their nature such as 'climatic, geological and meteorological hazards' (Bryant, 1991). Another way of categorisation is according to the duration of the occurrence. There are phenomena that occur as quickly as lightning, and others that occur with a slower rhythm. Into the first category, there are phenomena that take place in seconds (earthquakes), minutes (tornadoes), or hours (floods). The second category contains phenomena that need some months (some types of volcanic eruption), years (some types of landslide), or even centuries (climatic change) in order to manifest.

Further to this, some hazards are accompanied by secondary phenomena. Categorisation of this type of event is even more difficult. Examples are tidal waves or tsunamis, landslides or avalanches. These events can take place in seconds, minutes or hours after the occurrence of an earthquake.

Natural disasters can also be categorised based on the human capability to foresee them. For instance, there are some natural phenomena that are usually predictable using current technologies and scientific knowledge of relevant disciplines. These include some volcanic eruptions, typhoons, tornadoes, snow, fog, floods, hot, humid summer days, and droughts. These phenomena occur with warning. In particular, the IDNDR (1992) defines the term "prediction" as 'the statement of the expected time, place and magnitude of a future event'. In such cases, there is a lead time – that is the time between the forecasting and the actual occurrence of the phenomenon. Lead time is the period of a particular hazard between its announcement and its arrival and it is also used for the mobilisation of resources needed in relief operations. This is a particularly important feature, as people may utilise this time – where this is possible – in order to be ready to avoid the event or to respond to it as effectively and efficiently as possible.

However, there is no evidence-based method to predict some natural phenomena, which may have catastrophic results. Such natural phenomena include avalanches, earthquakes, forest fires, landslides and tidal waves.

On this basis, natural disasters may be classified and categorised according to:

- Their nature, such as climatic, geological and meteorological disasters;
- The duration of their occurrence;
- Their potential to cause secondary phenomena;
- The potential for people to foresee or predict them.

However, there are some natural phenomena which may belong to more than one category.

Table 3.1: Classification of Natural Disasters

	Foreseeable Natural Catastrophes							Unforeseeable Natural Catastrophes				
Variables / Type of Catastrophe	Drought	Hot, Humid Summer Days	Flood	Fog	Snow	Tornado	Volcanic Eruption	Avalanche	Earthquake	Forest Fire	Landslide	Tidal Wave
Prediction	√	√	√	√	√	√	√					
Lead Time	√	√	√	√	√	√	√					
Slow	√	√	√	√	√					√		
Sudden								√	√		√	√
Climatic	√	√	√	√	√	√				√		
Geological	√		√				√	√	√		√	
Meteorological	√	√	√	√	√	√						√
Magnitude									√			
Frequency	√	√	√	√	√	√	√	√	√			
Development of Dynamics						√	√	√	√		√	√
Cause of Secondary Phenomena	√	√	√		√	√	√		√			√

Table 3.1 is an attempt to classify natural catastrophic phenomena and it has been created based on a number of sources, including Assar, 1971; Burton et al, 1978; Alexander, 1993; Bryant, 1991; Coch, 1991; Abramovitz, 1999; EC, 2000; Lekkas, 2000; CEOS, 2001; EMA, 2002; EU, 2002; FEMA, 2002 and Buckle et al, 2003. It demonstrates the natural phenomena that under some extreme forms may be considered as catastrophic or disastrous for human assets and the various categories in which they may be classified according to the characteristics and parameters by which scientists study them. The main division has been made according to the ability of relevant scientists to foresee these phenomena or not. In addition to this, further categorisation has been attempted taking into consideration various parameters, such as lead time, magnitude, frequency, development of dynamics, whether they create secondary hazardous events, whether they have sudden or slow occurrence and whether they are climatic, geological or meteorological phenomena. According to the scope of the present study and because natural disasters, their implications and the ways to manage them cover a wide range, only the ones recognised as threats by the European Union (EU) for its Member States have been examined throughout this study.

The following sub-sections present the categorised natural catastrophic phenomena in more detail, through the establishment of their definitions, as well as the presentation of some statistical data related to their occurrence and the disruption they have caused to human organised societies in the past. In order to describe all of them in a rational and understandable order, one type of categorisation has to be employed. The categorisation of the disasters, which are presented next, is based on the capability of relevant scientists to foresee the natural phenomenon or not.

3.3.1 Foreseeable Natural Catastrophic Phenomena

This category covers the natural catastrophic phenomena for which people have the means to predict occurrence, as well as magnitude, place or time (EC, 2000; Lekkas, 2000). These events have an associated lead time, which may vary according to the time of the prediction and to some unexpected changes to specific variables of the phenomenon. The following sub-sections briefly explore each one of these natural phenomena, and are based on a literature review extracted from the research works of Bryant, 1991; McCall et al, 1992; Smith, 1992; Alexander, 1993; Coch, 1991; EC, 2000; Lekkas, 2000; Osti, 2004 and EM-DAT, 2006.

3.3.1.1 Hot, Humid Summer Days

The phenomenon of hot, humid summer days usually affects southern European countries. It does not occur very frequently and it occurs only during the summer season. It can be forecasted by the meteorological services. The heat responsible for the occurrence of the phenomenon is caused by heat waves. The term "heat wave" is defined as a long lasting period with extremely high surface temperature. This temperature may be between 40° and 50°C in the shade. Such long lasting periods of exposure in high temperature and humidity, along with the disruption of the everyday human activities, cause health problems for humans and animals. Large numbers of people become ill or die as a result of heatstroke and there are also numerous cases of sunstroke, as well as the health of weak persons deteriorating. This phenomenon has caused negative effects many times in the past to the economy of the areas, where it has occurred, as it also directly affects agriculture and animal husbandry.

3.3.1.2 Drought

Drought is a period of deficiency of moisture in the soil, such that there is inadequate water for plants, animals and human beings. The EU recognises this natural phenomenon as catastrophic for its Member States, in particular those located in the southern areas of Europe. Drought usually occurs during the summer period. During drought periods crops and plantations are destroyed and animals become lethargic causing problems in the local economy. Some other risks include the fact that the local population and animals may be poisoned by drinking water of poor quality, as well as the risk of occurrence of secondary disastrous phenomena, such as forest fires and aquatic pollution.

3.3.1.3 Flood

Floods are considered by the EU as the most frequent type of natural disaster affecting the continent. There are two types of flood:

- Slowly rising flood due to an abnormal rise in river levels after rain and/or due to melting snow, where its magnitude can be forecast; and
- Sudden flood due to heavy rain in certain regions or following another disaster (earthquake, tidal wave, etc.).

Water-induced disasters are usually compounded by the mismanagement of local water resources. During the occurrence of this phenomenon the number of victims may be very high due to the population density in these regions, which is generally above average due to the fertility of the land. In addition to this, a large number of people may be left homeless and there is usually disruption of communication and traffic networks, both with the outside world and within the region concerned.

3.3.1.4 Tornado

The phenomenon of tornado is considered as one of the most violent weather disasters. It is produced in a very severe thunderstorm and appears as a funnel cloud extending from the base of a cumulonimbus to the ground. Tornadoes move at great speed. They can be forecast in some cases and mainly occur in coastal regions possibly causing destruction over thousands of square kilometers. A tornado is usually accompanied by secondary catastrophic phenomena, and some of these include floods (due to rain or tidal waves) and very heavy storms. The occurrence of tornadoes usually causes major loss of livestock in addition to large numbers of killed, injured or missing people.

3.3.1.5 Volcanic Eruption

The phenomenon of volcanic eruption is characterised by the discharge of (aerially explosive) fragmentary ejects, lava and gases from a volcanic vent. The eruption usually results in the catastrophic covering of large areas of land with lava. The eruption may also result in the occurrence of secondary phenomena, such as floods, landslides and fires, as well as in technological accidents in chemical and nuclear facilities located within the disaster zone. The main eruption, along with the above-mentioned secondary phenomena, may result in large numbers of killed, injured and missing people, as well as resulting in numerous people becoming homeless from fear of a potential re-occurrence. In such situations, great interruption is caused to road, rail, air and telecommunication networks.

3.3.2 Unforeseeable Natural Catastrophic Phenomena

This section is concerned with the second category of natural phenomena, which have been recognised as threats by the EU for its member states. These are phenomena which occur suddenly and are, as yet, unpredictable.

3.3.2.1 Tidal Waves

Tidal waves are generated by the abrupt rise of tidal water caused by atmospheric activities. They move rapidly inland from the coast. Although when they occur their consequences are extensive, the areas at risk can be identified in advance. The occurrence of tidal waves usually causes a very high number of victims due to the suddenness of the event, as well as due to the population density in these regions, which is generally above average due to the fertility of the land. During the event there is usually a mass and stressed exodus of the population from the region with the effect that a large number of people are left homeless and numerous accidents are caused. In addition to this, there is disruption of communication and traffic networks, both with the outside world and within the region concerned.

3.3.2.2 Forest Fire

The occurrence of fires in forests usually causes extensive damage. They may start by natural causes, such as volcanic eruptions, or lightning, or they may be caused by arsonists or careless people, by those burning wood, or by clearing a forest area. The EU considers forest fires as a frequent event in the Mediterranean region, particularly during the summer season and it has categorised them based on past experience into three categories. These are:

- Fires affecting only a small area (85%);
- Major fires (13%); and
- Catastrophic fires (2%).

Forest fires destroy large-scale areas of trees and other types of plants. From an environmental point of view, destruction of the plant cover in the disaster regions can lead to ecological destabilisations like desertification, erosion, landslides and flash floods in some mountain regions.

3.3.2.3 Avalanche

The phenomenon of avalanche is defined as a rapid and sudden sliding and flowage of masses of usually unsorted mixtures of snow/ice/rock material. This phenomenon is usually observed in mountainous regions. In many cases, it can be forecast based on the characteristics of the local climate and topography, but without exact information about the time of any potential occurrence. An avalanche totally destroys everything in its path. The number of lives lost depends on the time of day, the nature of structures in the path of the avalanche, the time that passes before help arrives for the affected area, and the difficulty with which the disaster point can be reached.

3.3.2.4 Landslide

The term “landslide” is defined as all the varieties of slope movement, under the influence of gravity. More strictly the term refers to any down-slope movement of rock and/or earth masses along one or several slide surfaces. This particular phenomenon occurs suddenly and rarely can be forecast. The effects may be limited to the area around the occurrence and it may affect road, rail and communication networks.

3.3.2.5 Earthquake

The phenomenon of the earthquake is caused by the sudden break within the upper layers of the earth, sometimes breaking the surface, resulting in vibration of the ground which, if strong enough, may cause the collapse of buildings and destruction of life and property. An index of the seismic energy released by an earthquake was devised by C.F. Richter in 1935, (as contrasted to intensity that describes its effects at a particular place) expressed in terms of the motion that would be measured by a specific type of seismograph located 100km from the epicentre of an earthquake. This kind of disaster occurs suddenly and the effects may be limited to an area around the epicentre or it may affect a larger region, depending on the size and intensity of the earthquake. It usually causes a high percentage of destruction as a large number of people may be killed, injured or missing, as well as numerous people becoming homeless as their properties may be destroyed or they evacuate them from fear of a potential re-occurrence. Large-scale earthquakes are usually followed by secondary phenomena, such as floods, landslides and fires, as well as possibly causing technological accidents in chemical and nuclear facilities located within the disaster zone. The combination of these events may cause disruption to road, rail, air, and telecommunication networks, making it difficult for relief units to reach the victims and bring in relief supplies. Overall, after a major earthquake, there is the risk of epidemics due to pollution of the drinking water and decomposition of bodies, which have not been cleared away.

The above sub-sections briefly presented some of the most common natural phenomena for the member states of the EU, which in some forms may be considered as threatening for human societies. The occurrence of natural disasters usually represents a serious breakdown in sustainability and disruption of economic and social progress (Unesco, 2006). Therefore, it has been considered as essential to explore the implications of these disasters in the real world; this is taken up in the next section.

3.4 Implications of Natural Disasters in the Real World

Research studies over the last fifty years (Groat, 1999; UN, 2004; World Bank, 2005; Unesco, 2006) show that the number of losses in relation to lives, property and the environment caused by natural disasters is now becoming increasingly significant. This is due not only to the reason that more people are becoming ever more aware of the occurrence of these events due to the mass media and the expansion of communication methods, but also due to the fact that the number of natural catastrophic events is itself continuously increasing. As indicated by the UN (2004) 'over the last quarter of the century, the number of reported natural disasters and their impact on human and economic development worldwide has been increasing yearly'. While hazardous events wax and wane, and knowledge about them have been improved, the frequency of these events has remained relatively constant (Vink et al, 1998; Board on Natural Disasters, 1999). Natural disasters are increasing in terms of frequency, complexity, scope and destructive capacity. 'During the past two decades, earthquakes, windstorms, tsunamis, floods, landslides, volcanic eruptions and wildfires have killed millions of people, adversely affected the life of at least one billion more people and resulted in enormous economic damages' (Unesco, 2006).

The implications of the occurrence of natural catastrophic events to human organised societies are measured in terms of the losses they cause and these may be divided into three categories: the direct, the indirect and the secondary losses. According to the NRC (2006) 'the fact that disasters produce a host of primary, secondary and indirect effects means that the precise determination of physical impacts and social disruption is highly complex'. The following paragraph defines these three categories of loss based on literature extracted from the work of Reinhard, 2003; UN-ECLAC, 2003; and UN, 2004. The term "direct losses" refers to physical damage, including that to: productive capital and stocks (industrial plants, standing crops, inventories, etc.), economic infrastructure (roads, electricity supplies, etc.) and social infrastructure (homes, schools, etc.). Tierney et al. (2001) further point out that 'direct effects include the deaths, injuries, physical damage and destruction that are caused by the impact of the disaster agent itself'. The indirect losses include the downstream disruption to the flow of goods and services, such as any lower output from damaged or destroyed assets and infrastructure and the loss of earnings as income generating opportunities are disrupted. Disruption of the provision of basic services, such as telecommunications or water supply, for instance, can have far-reaching implications. Indirect costs also include the costs of both medical expenses and lost productivity arising from the increased incidence of disease, injury and death. However, gross indirect costs are also partly offset by the positive downstream effects of the rehabilitation and reconstruction efforts, such as increased activity in the construction industry. These kinds of occurrences 'can produce significant impacts and losses over and above those caused by the primary disaster agent' (NRC, 2006). Finally, the term "secondary losses" refers to the short and long term impacts of a disaster on the overall economy and socio-economic conditions. As examples may be considered the levels of household and national indebtedness, the distribution of income, scale and incidence of poverty and the effects of relocating or restructuring elements of the economy or workforce. In particular, NRC (2006) defines the secondary losses as 'the results from disruption in the flow of goods and services, unemployment, business interruption, and declines in levels of economic activity and productivity'. Despite the complexity of measuring primary, secondary and indirect losses, disasters can be distinguished conceptually from non-disastrous phenomena because:

- Disasters are a subset of societal problems;
- Regardless of their origins, disasters are acute events that involve a conjunction of physical conditions and social definitions at systemic as opposed to individual levels;
- Historical circumstances are not disasters until they are defined as such (Barton, 1989; Dynes, 1998).

Along with the number of extreme natural phenomena, it is evident that the number of losses in terms of human lives during and after the occurrence of such events has increased. At this stage it is considered useful to define "losses" in terms of human lives and affected people, with regard to the occurrence of natural disasters. As lost are characterised the 'persons confirmed as dead and persons missing and presumed dead' (IDNDR, 1992). However, as 'total affected are characterised the people requiring immediate assistance during the period of the emergency'. Such help may include basic survival needs like food, water, shelter, sanitation and immediate medical assistance (IDNDR, 1992).

Research data extracted from research works and official reports by Thompson, 1982; Shah, 1983; Abramovitz, 1999; EC, 1999; 2000; Lekkas, 2000; Gupta, 2003; Sarmo, 2003; Shaw, 2003; UN-ECLAC, 2003; europaworld, 2004; FEMA, 2004; EOS, 2005; UNICEF, 2005; CRED, 2006; Sapir, 2006; UN-ISDR, 2005; 2006 and others demonstrate the increase in the number of deaths and the rise in the total number of the affected Earth's population by natural disasters during the last few decades.

Over the past two decades (1980s and 1990s), 1.5 million people died in earthquakes, volcanic eruptions, tropical storms, droughts and other natural disasters. In 1998, 32,000 people lost their lives worldwide by the impact of such events. In the same year another 300 million people were displaced from their homes because of extreme weather. The following year (1999) earthquakes occurred in Greece and Turkey. These two events caused death to over 17,000 people (EC, 2000). Moreover, the statistical reviews referenced in the previous paragraph reveal that, on average, by the year 2004 natural disasters were causing 184 deaths per day globally.

In addition to the above, in 2005, there was an 18 per cent rise in the occurrence of disasters in relation to the previous year, leaving a total of 91,900 people dead. This increment has been caused mainly by the rising number of floods (by 57%) and droughts (by 47%), which affect large numbers of the population. In total 157 million people – seven million more than in 2004 – required immediate assistance, were evacuated, injured or lost their livelihoods. Despite this, loss of life was significantly lower than in 2004, during which 244,500 people died as a result of the occurrence of natural hazards.

Although the number of people killed during 2004 and 2005 is high compared to figures from the previous decade, most disaster-related deaths were due to a single incident of devastating proportions.

The following tables present figures from various sources revealing the large number of human lives lost due to natural disasters during recent years. Table 3.2, published by the International Federation of Red Cross and the Red Crescent Societies (2004), demonstrates the number of lost and affected humans in the five continents between the years 1984 – 2003.

Table 3.2: Number of Lost and Affected Humans in the Five Continents Between the Years 1984 – 2003 (source: International Federation of Red Cross and Red Crescent Societies, 2004)

Continent	Total Number of People Reported Killed (1984-1993)	Total Number of People Reported Affected (1984-1993)	Total Number of People Reported Killed (1994-2003)	Total Number of People Reported Affected (1994-2003)	Total Number of People Reported Killed (2003)	Total Number of People Reported Affected (2003)
Africa	579,454	152,866,203	47,648	156,416,500	5,810	20,951,399
America	59,390	32,250,982	76,557	49,317,904	2,026	3,739,486
Asia	341,143	1,425,145,631	480,001	2,342,913,147	37,860	228,895,146
Europe	40,537	7,524,471	65,526	23,028,114	31,046	1,121,047
Oceania	1,081	8,036,051	3,338	10,574,889	64	38,355
Total	**1,021,605**	**1,625,823,338**	**673,070**	**2,582,250,554**	**76,806**	**254,745,433**

Table 3.3, provided by the International Disaster Database (2006) demonstrates the number of people killed between the years 1990-2004 during and after the occurrence of natural disasters.

Table 3.3: Number of Killed People Between the Years 1990-2004 (source: DAT: The OFDA/CRED International Disaster Database, 2006)

Year	Drought	Earthquake	Heat	Flood	Slides	Volcano	Wave	Wild Fire	Wind Storm	Total
1990	0	42,884	992	2,203	214	33	0	0	4,926	**51,252**
1991	0	2,454	835	5,936	814	683	10	90	146,970	**157,792**
1992	0	4,035	388	5,367	1,070	0	0	122	1,335	**12,317**
1993	0	10,088	106	5,930	1,498	99	59	3	2,968	**20,751**
1994	0	1,237	416	6,413	280	101	31	84	4,081	**12,643**
1995	0	7,739	1,730	8,154	1,497	0	0	29	3,724	**22,873**
1996	0	569	300	7,171	1,155	4	27	45	4,217	**13,488**
1997	520	3,219	619	6,958	801	53	400	32	5,330	**17,932**
1998	260	7,391	3,225	9,689	981	0	2,182	109	24,657	**48,494**
1999	0	4,739	771	34,367	351	0	3	70	11,904	**52,205**
2000	370	216	922	6,429	1,023	0	1	47	1,138	**10,146**
2001	199	21,336	1,653	4,662	692	0	0	33	1,818	**30,393**
2002	533	1,634	3,369	4,122	1,149	200	0	6	1,112	**12,125**
2003	9	29,617	48,228	3,718	706	0	0	47	1,002	**83,327**
2004	1	882	239	6,957	357	2	226,435	14	6,513	**241,400**

Figure 3.1 provides a graphical representation of the total losses caused by the sum of natural disasters during the years 1990-2004 and is based on the numbers provided by the International Disaster Database in Table 3.3. It demonstrates a stable increase in human losses over the period of time examined and two very high values in 1991 and 2004. Certain peak periods of loss in the past can be explained by singular large events (such as Hurricane Andrew, the Northridge earthquake and the Indian Ocean Tsunami). However, these singular events alone do not completely explain the exponential rise in losses caused by natural hazards (EOS, 2005). The 2004 Indian Ocean tsunami accounted for 92 per cent, and the 2005 South Asian earthquake, for 81 per cent of deaths in each respective year.

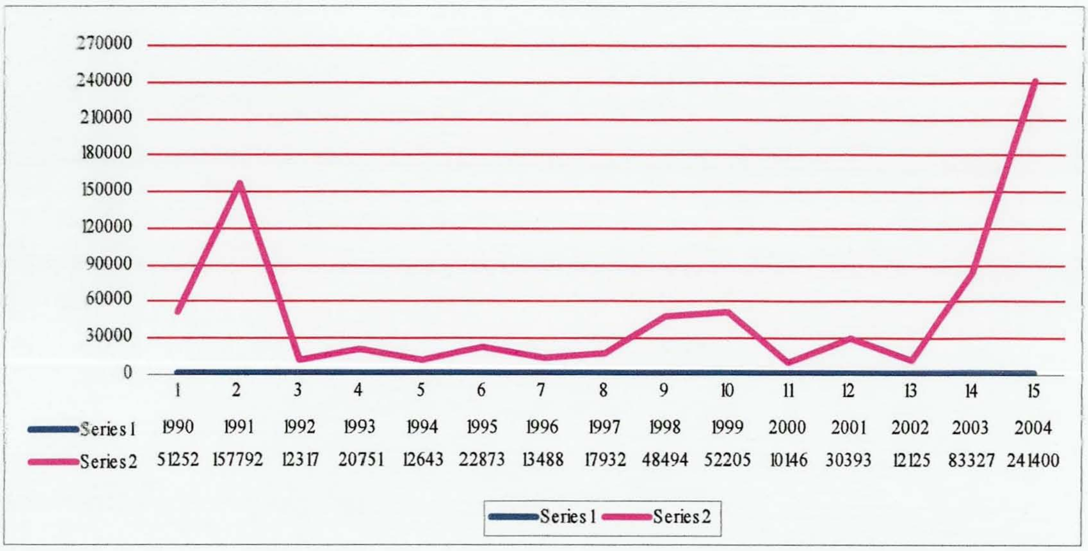


Figure 3.1: The Total Losses Caused by the Sum of Natural Disasters During the Years 1990-2004.

Apart from human losses, natural disasters cause damage to the general infrastructure of the area of their occurrence, such as to buildings and to the normal activities associated with everyday life. These damages are usually translated in terms of money. Therefore, cost is considered as another major issue related to the occurrence of natural catastrophic phenomena. A natural disaster is characterised as a very serious collision between the natural environment and the socio-economic system. In this respect, cost related bodies recognise as a disaster an event that causes material losses that cost over $1 million. However, assessing how much disasters cost nations and their communities is considered a major challenge. An NRC study (1999) concluded that such calculations are difficult in part because different agencies and entities calculate costs and losses differently. Moreover, no universally accepted standards exist for calculating economic impacts resulting from disasters and there is not a single agency responsible for keeping track of disaster losses. For any given disaster event, assessments of economic impacts may vary widely depending on which statistics are used. Such statistics may include direct or insured losses versus total losses. The following paragraphs present some examples of natural disasters, which caused economic disruption, along with the increase in the global cost of such events and are based on data extracted from Munich

Re, 2002; EC, 2004; FEMA, 2004; ISDR, 2004; EOS, 2005; World Bank, 2005; NRC, 2006; ISDR, 2006; and Worldwatch Institute, 2006.

The money spent globally to overcome natural disasters has increased over the years. Average annual economic losses caused by disasters were $75 billion in the 1960s, $138 billion in the 1970s, $213 billion in the 1980s, and more than $659 billion in the 1990s On average, the occurrence of natural hazards result in direct annual losses alone (crop and property) exceeding the figure of $7.6 billion. This figure does not include insured loss payments to individuals and businesses, disaster payments to individuals, businesses, or local governments, or indirect losses such as lost wages, business downtime, or environmental damage. During the 1990s the economic losses caused by the occurrence of natural disasters were greater than in the previous four decades combined, with the decadal annual mean loss steadily increasing, peaking at $14.4 billion. In particular, the cost of weather-related disasters in 1998 reached a record high of more than $92 billion, a 50% increase over the previous record of $61 billion in 1996. Natural disasters caused approximately $85 billion in economic losses worldwide in 2002, up 36% over the previous year. The total cost for the year 2004 was $92.9 billion, while in 2005 costs from disaster damage rose by 71% reaching the figure of $159 billion.

Most losses by natural disasters are caused in developed countries. However, the above estimates fail to capture the impact of disasters on poor countries that often are unable to provide exact numbers in relation to losses in terms of lives and livelihoods. Compared to developing countries, the absorptive capacity of developed countries is greater, the impact ratios on economies are smaller, and the recovery rates are more rapid. Further to these, 85% of the population of countries with medium or low economic development is exposed to natural disasters. The process of development has a major impact on disaster risk. In some countries, development means greater ability to afford the investments needed to build more disaster-resilient communities. Disaster resilience is defined as the capacity of a community that is exposed to hazards to adapt, by resisting or changing, in order to reach and maintain an acceptable level of functioning and structure. Resilience is determined by the degree to which the community is capable of organising itself to increase its capacity for learning from past disasters (UN, 1992; 2005; Bosher et al, 2007). In other countries, growth is accompanied by such development decisions that place more people and property at risk. Thus, rebuilding from disasters has been devastating to poor countries, as losses consume vast amounts of the limited available capital, significantly reducing resources for new investment. Figure 3.2 is based on the above figures and it illustrates the global cost related to natural disasters during the years 1996-2005.

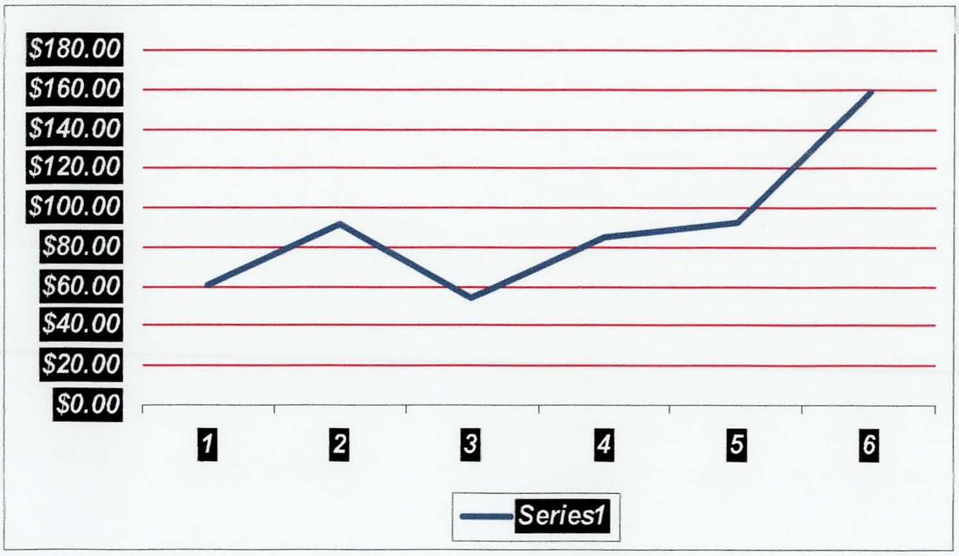


Figure 3.2: The Global Cost Related to Natural Disasters During the Years 1996-2005.

Overall, the cost of natural disasters to the international economy is over $60 billion per year, while in the United States alone the estimated cost of the impact of a major earthquake is around $200 billion. From these figures, one-third is spent on planning and the other two-thirds are spent on response to, and recovery from, the occurrence of natural disasters. Although some may argue that different sources provide different numbers in terms of both losses of life and economic cost caused by the occurrence of such events, the fact derivable from all the collected data is that extreme natural phenomena have significant human losses as a consequence. Widely known historical sources show that natural disasters have always occurred and will continue to occur on the planet, with often disastrous consequences.

According to Vink et al (1998) and the Board on Natural Disasters (1999) the reason for the growth of natural disasters is attributed to the fact that 'more people and property are placed in harm's way'. 'Human factors, such as population growth and migration to more hazard-prone locations, such as coasts are the more likely contributor to increased losses' (EOS, 2005). This is also supported by Unesco (2006), which points out that the massive concentration of population in hazard-prone areas or in cities and settlements where houses or infrastructures are not safely constructed or built or where land-use is poorly planned lead to disastrous effects after an earthquake, even at a low scale. An increase in the world's population causes an increase in the density of population within an area. The increase in population has led to the settlement of areas of the planet that were previously uninhabited, urbanisation, alteration of the natural environment, substandard dwellings and public buildings, inadequate infrastructure maintenance, as well as poverty exacerbation in numerous communities. NRC (2006) suggests that 'high-density developments associated with new urban forms can place more people, residential and commercial buildings and infrastructure at risk than conventional development on an equivalent land unit exposed to hazards'. Finally, the World Bank (2005) states that '3.4 billion people, more than half the world's population, live in areas where at least one hazard could significantly impact them'.

The following figures, published by the World Bank (2005), reveal the vulnerability to the occurrence of a natural catastrophic phenomenon and the possibility of people experiencing its consequences.

- Approximately 20 per cent of the Earth's land surface is exposed to at least one of the natural hazards evaluated;

- 160 countries have more than one quarter of their population in areas of high mortality risk from one or more hazards;
- More than 90 countries have more than 10 per cent of their population in areas of high mortality risk from two or more hazards;
- In 35 countries, more than 1 in 20 residents lives at relatively high mortality risk from three or more hazards;
- More than one-third of the United States' population lives in hazard-prone areas, but only one per cent of its land area ranks in the highest disaster-related mortality risk category;
- Poorer countries in the developing world are more likely to have difficulty absorbing repeated disaster-related losses and costs associated with disaster relief, recovery, rehabilitation and reconstruction.

Figure 3.3 demonstrates the areas of the planet which appear to be more vulnerable to future impact by natural disasters, showing in particular the high mortality risk.

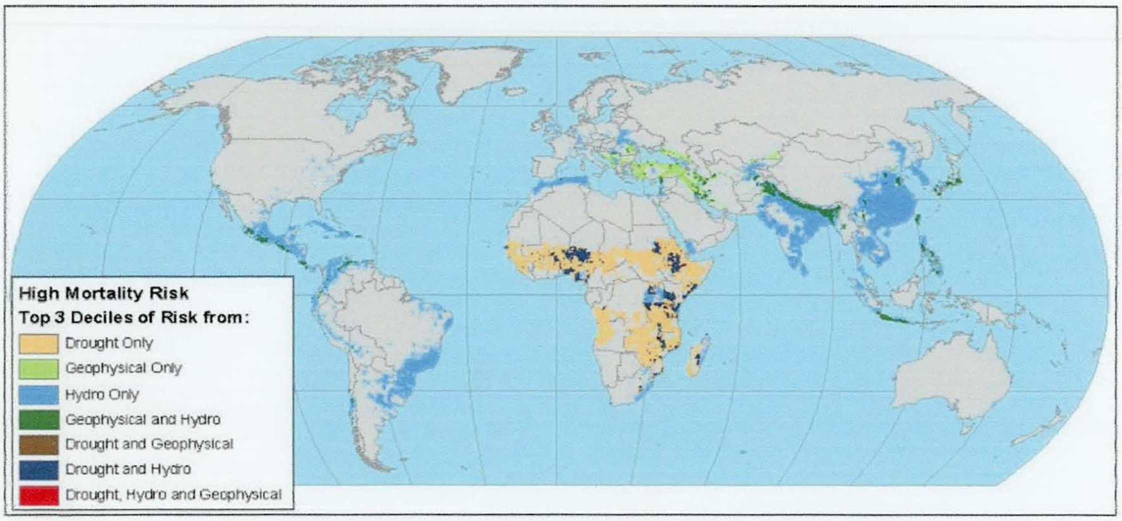


Figure 3.3: High Mortality Risk (source: The Earth Institute, 2005)

UN (2004) states that 'reported data on the cost of disasters relate predominantly to direct costs. Figures on the true cost of indirect and secondary impacts may not be available for several years after the occurrence of the disaster, if at all. The passage of time is necessary to reveal the actual pace of recovery and precise nature of indirect and secondary effects'. Ongoing research suggests that the secondary effects of disasters can have significant impacts on long-term human and economic developments. Most obviously, disasters affect the pace and nature of capital accumulation. The possibility of future disasters can also be a disincentive for investors. In examining the longer-term impact of the occurrence of disasters, it is also important to recognise that a disaster is not a one-time event but, rather, one of a series of successive events, with a gradual cumulative impact on long-term development (UN, 2004).

Figure 3.4 demonstrates the areas of the planet which appear to be more vulnerable to future impact by natural disasters, showing in particular the high aggregate economic risk in such areas.

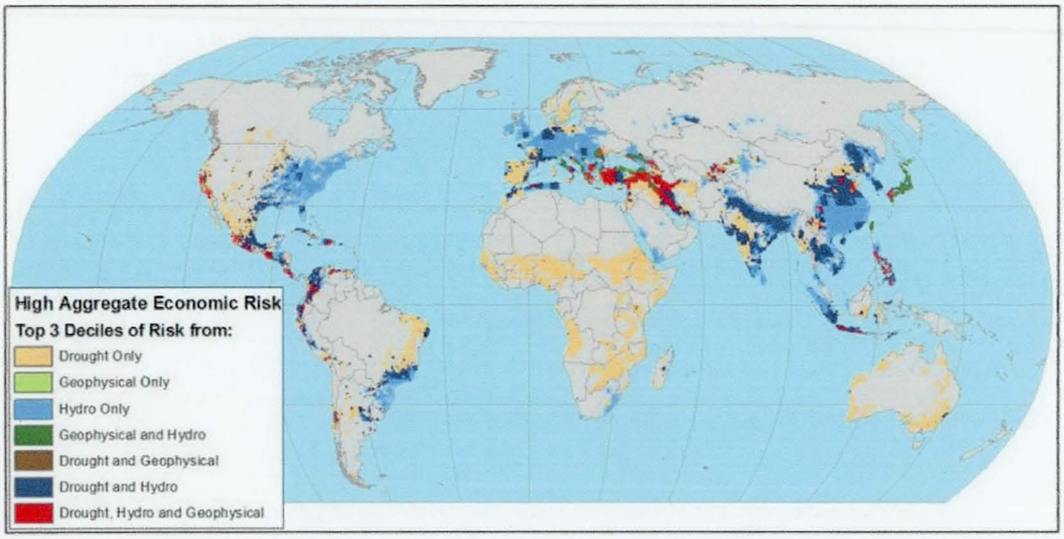


Figure 3.4: High Aggregate Economic Risk (source: The Earth Institute, 2005)

'The costs of natural disasters, including lives lost, homes destroyed and economies disrupted, have skyrocketed in this century, as the world's population has grown and has moved onto areas that are vulnerable to earthquakes, hurricanes, landslides, and other natural hazards' (Groat, 1999). With further population growth, expansion of public and private infrastructures, and continuing trends towards uncontrolled urbanisation and industrialisation, the risks of greater tragedies stemming from natural hazards are expected to increase in the next few years (Unesco, 2006). However, natural disasters always occur and people have to find ways to overcome their consequences on lives, property and the environment. Therefore, there is the need for integrated approaches in development policies and planning, to take into account disaster reduction and response goals to the overall benefit of the socio-economic development process. With this in mind, the following sections present the discipline responsible for the management of disaster and emergency situations caused by the occurrence of extreme natural phenomena. They highlight the importance of improving the management of the response to such catastrophic events.

3.5 Emergency Management

The following sub-sections define the terms of emergency and disaster and describe in detail the various stages need to take place in order to manage demanding situations caused by the occurrence of extreme natural phenomena.

3.5.1 Emergency Definition

The term "emergency" describes a situation caused to human organised society by the occurrence of an extreme natural phenomenon, which may be characterised as a hazard, catastrophe or disaster. The fact that one may occur suddenly or unexpectedly yields that it may cause even greater problems to the functionality of an organised community. Johnson (2000) points out that 'an emergency is a deviation from planned or expected behaviour or a course of events that endangers or adversely affects people, property, or the environment'. In this respect, there should be 'a need for immediate action in order to avoid harmful results' (Cambridge Dictionary, 2004). The term "emergency" is also defined as 'a sudden and usually unforeseen event that calls for immediate measures to minimise its adverse consequences' (IDNDR, 1992). In these circumstances, resources from local, regional and/or national public services are employed in order that such harmful results for humans and environment can be either avoided or reduced. 'When the normal local or national relief and public health service resources are not adequate, then emergency local, national or international resources must be called upon to cope with the situation' (Assar, 1971). Sometimes the effects of a natural disaster are so harmful that these services may not be capable of controlling the situation. In these cases, the situation exceeds the width of the emergency and it is then characterised as a disaster. However, there is no universally accepted definition for the term "disaster". This is because 'the definition of disaster is dependent upon the discipline using the term' (Shaluf et al, 2003).

As the aim of the present research work is to investigate and attempt to improve the response phase and not to prioritise the actions in terms of planning and response, the questions that arise are: How much money is usually spent and to what extent are the actions during the response stage planned in advance, and are they coordinated and communicated effectively and efficiently during the operation? These questions will be examined in Chapter 4, where the method of case studies will be employed.

3.5.2 Emergency Management and its Four Phases

As natural disasters are avoidable forces the best that man can do is to seek protection or to exercise vigilance and use the knowledge he has acquired to defend himself from these forces or alleviate their consequences (Assar, 1971; Shaw et al, 2003). In particular, humans have either to increase the lead-time by improving the prediction methods (for phenomena that currently can be predicted) or to identify methods to predict all natural catastrophic phenomena. In the meantime, other methods would involve the improvement of the effectiveness and efficiency of methods used within the given lead-time. Obviously, this is applicable to those natural disasters where predictions can be made. For all other cases, it is argued that there is one way for people to overcome their implications and this involves the improvement of methods associated with planning and responding to the occurrence of natural disasters. This forms the broader area of investigation of this study. The fact that there are natural phenomena, which occur without warning, adds to the complexity of the situation as a whole. The 'lack of warning makes avoidance difficult' (Hodgkinson and Stewart, 1991) or impossible. Consequently, for people to avoid these catastrophic results there is the need to take appropriate actions before the occurrence of the potential hazards in order to minimise damage.

A professional discipline called emergency management has been established in order to set 'a range of measures to manage potential risks related to natural catastrophic phenomena to communities and the environment' (EMA, 2002). The term "risk" is defined as 'the expected losses (of lives, persons injured, property damaged, and economic activity disrupted) due to a particular hazard for a given area and reference period. Based on mathematical calculations, risk is the product of hazard and vulnerability' (IDNDR, 1992).

Although it could be argued that the actions that people take in order to cope with disasters often take place after the occurrence of a natural disaster, these actions have to be organised and planned before the event. Much research is currently being conducted in the area of emergency management to improve the ways that catastrophic phenomena are managed. The ultimate aim of emergency management is to 'save lives, prevent injuries, and protect property and the environment if an emergency occurs' (Nalls, 2003). In particular, the term "planning" includes the set of activities necessary to analyse and document the possibility of a natural phenomenon to cause an emergency or disastrous situation and the potential consequences or impact on life, property and the environment. According to Green (2001) and Johnson (2000) this includes the assessment of the hazard, the potential risks, and the planning, preparedness, response, and recovery needs and requirements. Fundamental to emergency planning is the identification of the demands that characterise the disaster response environment and developing the management capabilities required to deal with them (Paton and Jackson, 2002). This is the priority of the emergency management discipline, as it 'is the body of policy, administrative decisions and operational activities, which pertain to the various stages of a disaster at all levels' vulnerability' (IDNDR, 1992). According to the same source, the term "levels of disaster" means that a disaster consists of many different phases, where 'disaster phases, cycle, or continuum are the pre- and post-disaster periods subdivided into particular actions' vulnerability'.

Effective emergency management has to plan, organise and control the whole cycle of a disaster. Although EMA (2002) points out that emergency management 'in a multicultural society should meet the specific and challenging needs of all members of our community, through the provision of a responsive and inclusive service', it could be argued that all members of our community are not the same. Although individual values have to be respected, these should be beyond the scope of emergency management procedures and not interfere with its primary goal, which is to minimise losses. For this reason there is the need for emergency management experts to have a generic plan, which will enable a certain set of standards to be met during practice. This generic plan is divided into four different phases, in order to allow emergency managers be able to organise, analyse, plan, make decisions, and finally assign available resources to mitigate, prepare for, respond to, and recover from all the effects of all catastrophic events (Nalls, 2003; Trim, 2003; Shaw et al, 2003). These four phases are set and controlled by disaster legislation, which 'is the bodies of law that govern and designate responsibility for disaster management concerning the various phases of disaster vulnerability' (IDNDR, 1992). The following sub-sections describe the emergency management cycle and the four phases, which it comprises, namely mitigation, preparedness, response and recovery.

3.5.2.1 Mitigation

The first phase of emergency management includes all 'the activities that actually eliminate or reduce the probability of a disaster' (Johnson, 2000). This is called mitigation and includes the long-term activities designed to reduce the effects of an unavoidable disaster. The phase of mitigation also includes 'the measures taken in advance of a disaster aimed at decreasing or eliminating its impact on the society and the environment' (IDNDR, 1992). NRC (2006) further supports this by pointing out that mitigation includes the interventions made in advance of disasters to prevent or reduce the potential for physical harm and social disruption. These actions take place through the procedure of prevention, which according to the UN-DHA (1992) 'encompasses activities designed to provide permanent protection from catastrophic phenomena'. It includes engineering and other physical protective measures and also legislative measures controlling land use and urban planning. All the above-mentioned actions, when they are made in a scientific and professional maner are able – to a degree – to 'reduce an area's vulnerability to damage from future disasters' (Mileti, 1999). There are two major types of hazard mitigation; structural and non-structural mitigation. Structural mitigation involves designing, constructing, maintaining, and renovating the physical structures and infrastructure to resist the physical forces of disaster impacts. Non-structural mitigation involves all the efforts to decrease the exposure of human populations, physical structures, and infrastructure to hazardous conditions. The phase of mitigation is considered a very important step in emergency management, as it has to be taken into consideration in everyday infrastructure developments and land management.

3.5.2.2 Preparedness

Like mitigation, the second phase of emergency management – preparedness – also takes place before the occurrence of a potential catastrophic phenomenon. Although it is impossible for people to stop the occurrence of natural phenomena they can take 'sustained actions' in order 'to reduce or eliminate long-term risk to people, property and the environment from hazards and their effects' (Nalls, 2003). Therefore, the professionals involved have to be prepared to face a disaster and its results. Thus, the phase of preparedness includes actions taken in advance of disasters to deal with anticipated problems of emergency response and disaster recovery (NRC, 2006). According to Johnson (2000), 'preparedness is the set of activities necessary to the extent that mitigation measures have not, or cannot, prevent disasters'. The UN-DHA (1992) supports this and defines preparedness as 'the activities designed to minimise loss of life and damage, to organise the temporary removal of people and property from a threatened location and facilitate timely and effective rescue, relief and rehabilitation'. In particular, actions during preparedness include the development of formal disaster plans, the training of first responders, the maintenance of standby human, material, and financial resources, and the establishment of public education and information programs for individual citizens, households, firms, and public agencies (NRC, 2006). In order for all of these specific actions to take place and their aims to be met many different bodies collaborate. The collective and collaborative work of governments, organisations and individuals develop plans to save lives and minimise the damage caused by disasters (Johnson, 2000). Preparedness also involves building an emergency response and management capability before the occurrence of the event in order to facilitate an effective response when needed (Mileti, 1999).

Overall, the phase of preparedness of a community for a catastrophic scenario involves much collection of scientific knowledge and evidence; it needs collaborative management work and training of the community, in order to be able to face the real disaster when it occurs. This is clearly pointed out in Nalls' (2003) definition of preparedness, which defines it as 'the process of building the emergency management program to effectively prepare for, mitigate against, respond to, and recover from any hazard by planning, training, and exercising'. Disaster preparedness affects emergency response and recovery, and the experience of disasters has important consequences for the level of preparedness, the conditions of vulnerability and mitigation adjustments (Bankoff, 2004).

3.5.2.3 Response

As extreme natural phenomena are not seen as controllable events (Hodgkinson and Stewart, 1991), communities have always to be ready to respond to them when they occur and cause emergency or disastrous situations. It is therefore clear that the phase of response is the first reaction of people to an emergency/disaster and it takes place during or immediately after the occurrence of a catastrophic phenomenon. 'Response refers to the actions need to be taken immediately before, during and after a disaster occurs (in order) to save lives, minimise damage to property and environment and to enhance the effectiveness of recovery' (Mileti 1999). CEOS (2001) supports this by pointing out that 'response is the mapping of damage extent and nature; primarily for purposes of relief'. In particular, emergency response includes all the activities related to the issue and dissemination of predictions and warnings, the evacuation and other forms of protective action, the mobilisation and organisation of emergency personnel, volunteers and material resources, the search, rescue and care of casualties and survivors, the assessment of damage and needs and the restoration of essential public services (NRC, 2006).

Although humans – by nature – avoid thinking that something adverse will happen, and in particular "at least not to us", history has revealed that hazards and disasters occur everywhere and to anyone. Therefore, activities are designed to provide emergency assistance for all potential victims. They also seek to stabilise the situation and reduce the probability of secondary damage and to speed recovery operations (Johnson, 2000). In relation to 'secondary damage' and to 'speed recovery operations', Nalls (2003) points out that the role of response is the 'conduction of emergency operations to save lives and property by positioning emergency equipment and supplies; evacuating potential victims; providing food, water, shelter, and medical care to those in need; and restoring critical public services'. One of the most important aspects that needs to be valued through the chaotic situations caused by disasters is the safeguarding of human life. This has been widely recognised by governmental bodies and organisations, as well as by the United Nations, which points out that 'disaster response is a sum of decisions and actions taken during and after a disaster, including immediate relief, rehabilitation, and reconstruction' (IDNDR, 1992).

In addition to the above, during the phase of response there is the 'need for cooperation of a lot of specialists from different disciplines, in order for human lives to be saved' (Kiriazis and Zisiadis, 1999). The information required in the first hours after the occurrence of the event is not necessarily the same as that required days or weeks afterwards, e.g. mapping damage for insurance loss estimation (CEOS, 2001). Although the phase of response takes place immediately after the occurrence of a disaster, it operates through continuing action several hours or days after the event and it prepares for the activities of the fourth phase of disaster management, namely recovery.

3.5.2.4 Recovery

The term "recovery" has been defined in a number of different ways including the definition that Emergency Management Australia (EMA) established in 1996: 'Recovery is the coordinated process of supporting disaster-affected communities in reconstruction of the physical infrastructure and restoration of emotional, social, economic and physical well-being'. In addition to this, the Victoria State Emergency Response Unit (VSERU) in 2000 defined the phase of recovery as 'an enabling and supportive process, which allows individuals, families and communities to attain a proper level of functioning through the provision of information, specialist services and resources'. Another definition established by the National Research Council (2006) is that recovery is the 'activities related to the re-establishment of the pre-disaster social and economic routines (education, cultural activities, production, distribution, and consumption), the provision of financial assistance and other services, such as mental health care to victim populations, replacement and repair of damaged and destroyed housing and business properties and, in some cases, the determination of responsibility and legal liability for the event'.

The activities that take place during the phase of recovery can be divided into two categories: Short-term recovery activities, which take place in order to restore vital support systems (Mileti, 1999) to minimum operating standards (Johnson, 2000), and long-term recovery activities, which have as their goal 'to return life to normal' (Mileti,

1999) or to 'improved levels' (Johnson, 2000). These activities 'may continue for a number of years after the disaster' (Johnson, 2000). 'Recovery involves the rebuilding of communities so individuals, businesses, and governments can function on their own, return to normal life, and be protected against future hazards' (Nalls, 2003). This statement implies that during the recovery phase, long-term actions take place considering the phase of preparedness as the first activity of disaster management. Therefore, someone could argue that disaster management works as a cycle, in order for people's communities to be always ready to mitigate against, prepare for, respond to and recover from disasters. Figure 3.5 depicts a graphical representation for this four-phase continuous cycle of the emergency management process.

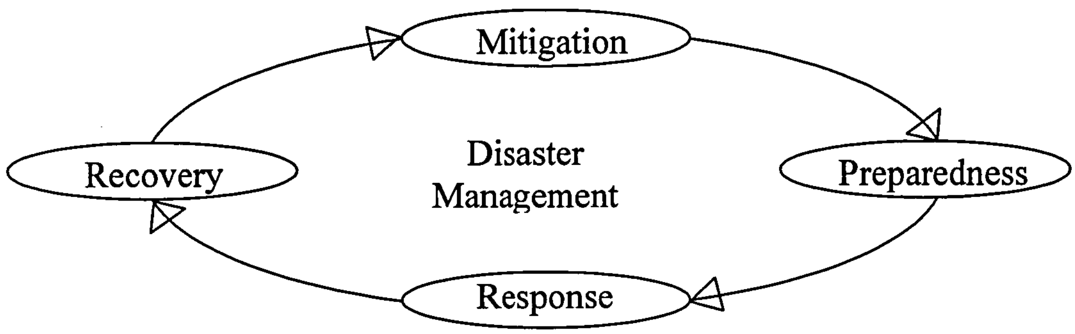


Figure 3.5: The Four Phases of Disaster Management

3.6 Identification of the Authorities Involved in the Emergency Management Process

As natural disasters are considered a threat and of great risk to people, property and the environment, specific bodies have been funded at international, national, regional and local level, in order to cope with them. These bodies act under the relevant bodies of law and in line with the principles of the emergency management discipline.

In particular, several international bodies, such as the North Atlantic Treaty Organisation (NATO), the United Nations (UN) and the European Union (EU) have recognised the great problem related to the losses to humanity caused by the occurrence of natural disasters. Therefore, they have funded relevant departments responsible for the application of emergency management operations, as well as for the improvement of the relevant processes through further research into natural catastrophic phenomena and investigation of the current and future needs of humanity.

NATO is acting through the Euro-Atlantic Disaster Response Coordination Centre (EADRCC), which was founded in 1998 as the focal point for coordinating disaster relief efforts of the 46 Euro-Atlantic Partnership Council (EAPC) nations in case of natural or technological disasters within the EAPC geographical area' (NATO, 2003). The aims of EADRCC are:

- Informing the Secretary General of NATO and through him the EAPC, as well as the Senior Civil Planning Committee (SCPC) about disasters occurring in countries covered by EAPC and requests for international assistance;
- Coordination of the response to disasters within the EAPC area upon the request of the stricken country;
- Promotion of EAPC countries' participation in the non-standing Euro-Atlantic Disaster Response Unit (EADRU); and finally
- Action as an information-sharing tool for EAPC nations on disaster relief.

The above-mentioned activities take place in close cooperation with the United Nations Office for the Coordination of Humanitarian Affairs (UN-OCHA). The OCHA was founded in 1998 and 'it carries out coordination function primarily through the Inter-Agency Standing Committee, which is chaired by the Emergency Relief Coordinator (ERC)' (UN, 1998).

The bodies presented above ensure the response to complex emergencies and disasters. Their actions include the need for assessment, coordinated appeals, field coordination arrangements and the development of humanitarian polices, through an inter-agency decision making process.

On the same basis, the International Civil Defense Organisation (ICDO), which is an intergovernmental organisation, was founded. According to ICDO (2004) its objectives include the 'contribution to the development by States of structures ensuring the protection and assistance of populations and safeguarding property and the environment from natural or man-made disasters'. It has also the role of federation, which:

- Brings together the capacities of the national structures of all its members in order to set common objectives; and
- Gives to the national protection structures common identity based on the universally recognised values.

The bodies of the UN and NATO participate in the response phases of emergency situations caused by natural disasters when the national relief units are not able to cope. With the same rationale, the EU becomes involved in the management of emergencies occurring in its member states. The management of natural disasters within the EU member states broadly follows the main phases described in Section 3.5. The key differences lie in the specific organisations responsible, the geographical and geological characteristics of each country, the population, the infrastructure and, more importantly, the type of natural catastrophic phenomena usually occurring in each area. Emergency management within the EU is represented by the body of Civil Protection (CP). The primary aim of the European CP is 'to support and encourage efforts made at national, regional and local level' (EC, 2000). A detailed examination of the aims, objectives and organisation of CP takes place in Chapter 4 of the thesis, where two Member States of the EU have been chosen for investigation as case studies. This familiarises the reader with the role and the specific aims and practices of CP, as well as identifying the other bodies involved in the management of the consequences of natural disasters.

3.7 Recognition of Constraints in Relation to Managing Natural Disasters

Michalowski (1991) points out that 'emergency management requires flexibility in decision support and ability to respond to varying situations because the scale of the residual effects varies according to the type and scale of the disaster'. Bringing in expertise from different parties is essential as 'emergency response involves multiple organisations and teams, geographically distributed operations and a high need for coordinated control and decision making' (Graves, 2004). This will assist in managing these situations with a more informed and holistic approach. However, this may also lead to numerous misunderstandings, as each one of the involved parties has their own perception in a particular situation (Asimakopoulou et al, 2006). During emergency response management 'the team members often hardly know each other and frequently have to work co-located. A crisis team has to perform many tasks partly in parallel and partly in succession during fighting a disaster (Rijk, and Berlo, 2004). 'In the case of an unplanned incident, a common understanding of the current situation by first responders, incident commanders and supporting organisations ensures a quick response to contain the consequences' (Titan, 2002). However, many departments and organisations cannot share data. In addition to this, during an emergency 'people revert to established rules of behavior and the creativity and improvisation that are essential to successful crisis response, are compromised. This also occurs when critical information is present but hidden in the "noise" due to information overload – a phenomenon which is quite common in computer-based communication systems and likely to be exacerbated in emergency situations (Hiltz and Turoff, 1985; Turoff et al, 1993; Turoff 2002; and Alles et al, 2004). These limitations may lead to major breakdowns, which in the particular field of emergency management could lead to important losses, such as human lives. 'In practice, the different parties are not always aware of each other which results in a lack of communication, coordination and collaboration and consequently, in a less effective crisis response organisation' (Oomes, 2004). Therefore, 'the way professionals and specialists contribute their knowledge and experience has to be structured carefully' (The Chartered Institute of Building, 2002). However, even the best-structured technique can be unsuccessful if it is not communicated effectively.

In the particular field of emergency response 'information exchange during an emergency situation can be very diverse and complex' (Carle et al, 2004) therefore, 'people must take life and death decisions and take actions based upon incomplete information' (Alles et al, 2004). The nature of information during emergencies can be characterised as static or dynamic. 'Static information does not change during the emergency situation and group's data, such as the technical site description, the safety assessment reports and procedures. The dynamic information group's data that changes during the emergency contains information on the evolution of the incident, the radiological survey data, the radiological impact prognoses based on the type of accident, meteorological information, information on casualties, deployed and available resources etc.' (Carle et al, 2004).

In general, the need to bring together the intellectual resources of the parties involved within the same environment communicating effectively and efficiently has led to the development of relevant collaborative computer-based systems. The main purposes for the development of such technologies are: to form appropriate computerised environments in order to overcome human cognitive limitations, and to provide decision makers with a holistic view of the concerned situation so they can manage it (Maracas, 2002; Turban and Aronson, 2001). The rationale is based on Simon's decision-making theory (Simon, 1977). In particular, Simon's well-known "bounded rationality" theory appreciates that despite the attractiveness of optimisation as a decision-making strategy, its practical application is problematic. This is due to the fact that it is not feasible to attempt to search for every possible alternative for a given problem. Simon exemplified this by defining the term "problem space". A problem space represents a boundary of an identified problem and contains all possible solutions to that problem: optimal, excellent, very good, acceptable, bad solutions and so on. The rational model of decision-making suggests that the manager as a decision maker would seek out and test each of the solutions found in the domain of the problem space until all solutions are tested and compared. At that point, the best solution would be known and identified. However, what really happens is that the manager as a decision maker actually simplifies reality since reality is too large to be handled given human's cognitive limitations. This narrows the problem space and clearly leads the decision-maker to attempt to search within the actual problem space that is far smaller than the reality. By searching in a narrow space, the decision maker will most likely not choose an optimal solution because the narrowed search of the actual problem search space makes it improbable that the best solution will ever be encountered. Figure 3.6 illustrates Simon's "bounded rationality" theory.

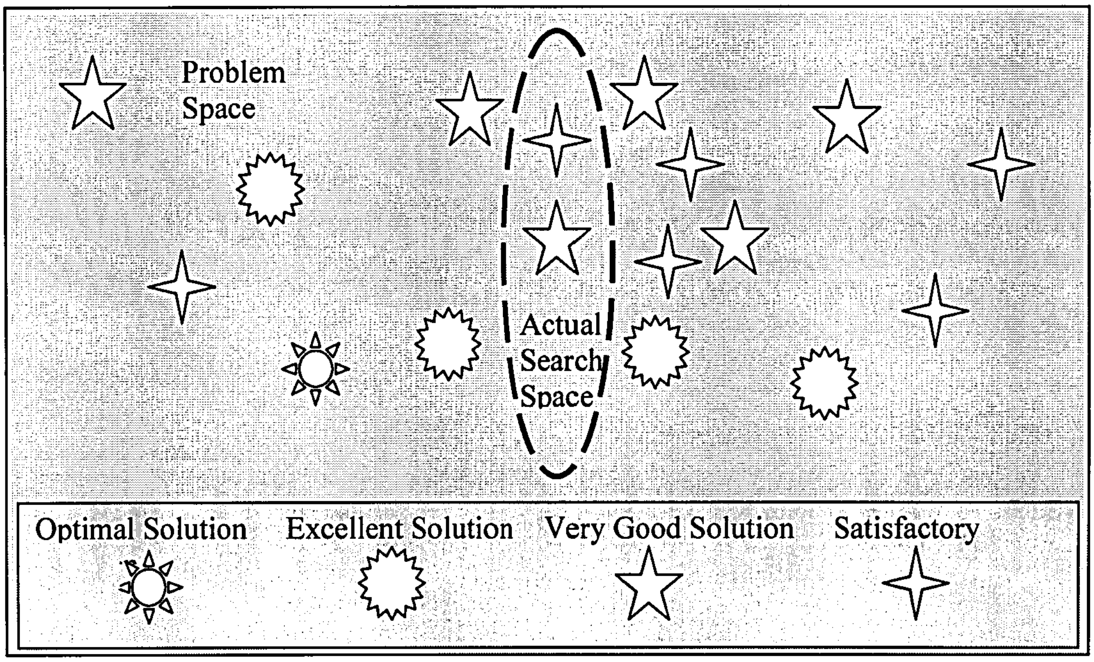


Figure 3.6: Simon's "Bounded Rationality" Theory, 1977

'In the specific context of civil protection and emergency management, electronic based methods for communication and management involve the process of exchanging information digitally' (Howard et al, 2002). In particular, current electronic systems enable users to communicate either via, for example, e-mail, office networks and project extranets. Modern technologies have been developed in order to reduce the exposure of the physical and built environment and the other elements of socio-economic life to extreme natural phenomena and disasters (Unesco, 2006).

However, there is still room for improvement as it has been emphasised that there is the need 'to develop better structured and coherent procedures for decision-making regarding protective actions for the population and the environment' (Turcanu et al, 2004). 'Large-scale emergencies usually require the involvement of the national crisis management organisation in support of, or to coordinate the response of, local and regional emergency management teams. Information flow between the national and local organisations and within the national ministries and agencies involved in a multi-disciplinary response can be challenging, slow and ineffective, which in turn often creates a significant disconnect between the national and the local response' (Otten et al, 2004). The above mentioned disconnect further involves the fact that 'many small communities do not have the resources, personnel, nor the expertise to develop a set of requirements to assist them in managing their activities as they pertain to emergency response' (Bui and Lee, 1999). In addition to this, 'while information technologies and advanced modeling techniques continue to expand how society can limit and manage emergencies, flexibility remains crucial to the success of planning and response operations' (Mileti, 1999).

One of the major problems during emergency response management is that Information and Communication Technologies (ICT) continue to break down during crises. Overall, recent emergency management approaches are characterised as inefficient 'because of their unstructured poor resource management and centralised nature with fixed hierarchical instructions' (Scalem et al, 2005). 'During a major incident many segmented organisations must come together to plan, coordinate and manage a coordinated response to the incident. Sharing of accurate information in a timely manner – while limiting redundant requests and replies for the same information – is essential for an effective coordinated response' (Graves, 2004).

This section has presented the literature-based findings about constraints of managing emergency situations in terms of response. This included references to Simon's decision making theory, which highlighted that decision makers in general will most likely not choose an optimal solution because the narrowed search of the actual problem search space makes it improbable that the best possible solution will ever be encountered. However, there is the need to further explore these findings to find out what is happening in real-world response operations. To this extent, the method of case studies (including two member states of the European Union) has been employed. This exercise explores the ways in which ICT methods and equipment are used for communication and coordination purposes during emergency response management operations. It also highlights the satisfaction of the emergency management stakeholders about these methods, in terms of effectiveness and efficiency. This will be pursued in Chapter 4.

3.8 Summary

This Chapter has presented a literature-based review in relation to the first objective of the study. In particular, it has defined the terms of natural disasters, emergency management and its four phases. It has also highlighted the implications of the occurrence of extreme natural phenomena in human organised society. It established the need for organised action as a response to these situations. On this basis, relevant international relief bodies were presented. Finally, it concluded by pointing out concerns related to human cognitive limitations and their relationship to managers attempting to make relevant decisions, as well as the implications in managing emergency response operations including communication breakdowns when simultaneous interactions need to take place between experts from the diverse authorities involved in a relief operation. Therefore, the need for reviewing current ICT methods used in relief operations was established and this follows next.

Chapter 4 Case Studies of Emergency Management in Europe

4.1 Introduction

Chapter 4 is concerned with the administrative organisation of the authorities responsible for emergency management, as well as with the ICT currently in use by them during the response operation to emergency situations caused by natural disasters. The effectiveness and the efficiency of this ICT are critically discussed and assessed. In order for a clear picture to be drawn, two member states of the European Union (EU) have been selected and employed as case studies for this part of the research, namely Greece and the United Kingdom (UK). The authorities involved in emergency response management have been identified and their operational procedures presented. The findings discussed in this chapter are the outcome of a series of one-to-one structured interviews conducted with the leaders of the authorities responsible for emergency management and other relevant stakeholders representing the two member states of the EU taken as case studies.

4.2 Emergency Management in the European Union

The term “civil protection” ‘has gradually come into use around the world as a term that describes activities, which protect civil populations against incidents and disasters’ (Mauro, 1996). The body for Civil Protection of the European Union (EUCP) in the field of natural disasters is concerned with the member states of the Union and the three European Economic Area countries (Norway, Iceland and Liechtenstein). It also supports disaster relief in countries of North Africa and in some parts of the Middle East. The governments of the EU member states first formally agreed to coordinate their civil protection strategies at a ministerial meeting, which took place in Rome in 1985. ‘Between 1985 and 1994, they approved a number of preliminary initiatives that laid the foundations for today’s extensive coordinated approach for dealing with and planning for major disasters’ (EU, 2002).

The primary aim of the EUCP body is to 'support and encourage efforts made at national, regional and local level' (EC, 2000). The objectives of the Community's co-operation in the field of civil protection are to:

- Support and supplement efforts at national, regional and local level with regard to disaster prevention, the preparedness of those responsible for civil protection and the intervention in the event of disaster;
- Contribute to informing the public with a view to increasing the level of self-protection of the European citizens;
- Establish a framework for effective and rapid co-operation between national civil protection services when mutual assistance is needed;
- Enhance the coherence of actions undertaken at international level in the field of civil protection especially in the context of co-operation with the candidate Central and Eastern European countries in view of enlargement and with the partners in the Mediterranean region (EC, 2002).

However, 'the EU's various civil protection cooperation strategies are not designed to replace national systems' (EC, 2002). The body acts as a coordinator when international assistance and relief units are required. During these situations the EUCP ensures that the appropriate personnel and any other relevant resources are dispatched to the disaster area as quickly as possible. It also acts as a guide for the member states in order for them to create and improve their own emergency plans. Each country should follow a series of "planning principles", which have been developed by the EUCP and these serve as general guidelines for the creation and improvement of individual emergency planning.

4.3 Approach to Case Studies

As it has been justified in Chapter 2 the method of case studies is used to further explore limitations identified in the previous chapter.

The two member states of the EU that were selected and adopted for this exercise are Greece and the United Kingdom (UK). Greece and the UK have been selected because the author has access to the authorities involved to emergency management and to the regional and local governmental bodies under examination, and therefore this enabled data gathering. Both countries follow the same European guidelines to organise their Emergency Management (EM) departments and in general their emergency management procedures. However, they have a slightly different approach to their application, as they have different needs. The difference is mainly related to the fact that the natural phenomena that occur in extreme forms in each county are different; other differences, such as organisational issues in the two countries, are covered in Sections 4.5 and 4.6.

Greece is located in the Mediterranean Sea, which is an area more vulnerable, amongst other things, to the occurrence of geological-related natural phenomena without lead-time including earthquakes, avalanches, or volcanoes. As stated in Chapter 3, this area experiences much seismic activity, often very hazardous for its citizens. On the other hand, the UK, due to its geographical position and its geological nature does not have a significant record of such events. The UK usually has to overcome weather-based hazards, such as heavy rain, snow, floods or storms, which often cause disastrous situations for the citizens in the area of their occurrence. Examples are the storms in Southern England in 1990 (with over 45 fatalities), and the flooding on the Welsh coast during the same year and in the summer of 2007. However, scientists can often foresee these events and therefore, the authorities responsible for the management of the emergencies they may cause are provided with a lead time, which can prove useful for warning people and for the preparation of the exact response methods and individual emergency response units.

4.4 Case Study 1: Greece

Greece – officially the Hellenic Republic – is a country located on the southern end of the Balkan Peninsula. It is bordered by Albania, the Former Yugoslav Republic of Macedonia (FYROM) and Bulgaria to the north and by Turkey to the east. The Aegean

Sea lies to the east and south of mainland Greece, while the Ionian Sea lies to the west and they both feature a large number of islands. The capital city of the country is Athens. Greece is a Member of the European Union (EU) since 1981, member of the Economic and Monetary Union of the European Union since 2001 and member of the North Atlantic Treaty Organisation (NATO) since 1951.

4.4.1 Public Administration in Greece

The law numbered 3013 upgraded the role of Civil Protection in Greece in May 2002 'emphasising the importance of citizen protection and assigning roles to local authorities' (GSCP, 2005). According to this statement, the government has recognised the importance of the protection of public life, health, property and the environment through the application of the emergency management practices – as described in Section 3.5 – in all administrative levels of the country. Therefore, it is essential for the purpose of the study to examine and understand the administrative model of the country and further explore the meaning of the term "local authorities" along with their roles and responsibilities, with particular reference to emergency response management.

According to the Hellenic Sydagma (the Constitution) the form of Government in Greece is Presidential Parliamentary Democracy and the public administration of the country is organised at national, regional and local levels. That is to say, there is the central Government, which is responsible for running the country through the 300 Members of Parliament; the 23 Ministers; and the Prime Minister of Greece, who are elected by the public every four years; and the President of the Hellenic Republic, who is elected by the Members of Parliament every five years.

Figure 4.1 illustrates the administrative organisation of the Greek Government, presenting the leaders of each administrative level and their hierarchical order.

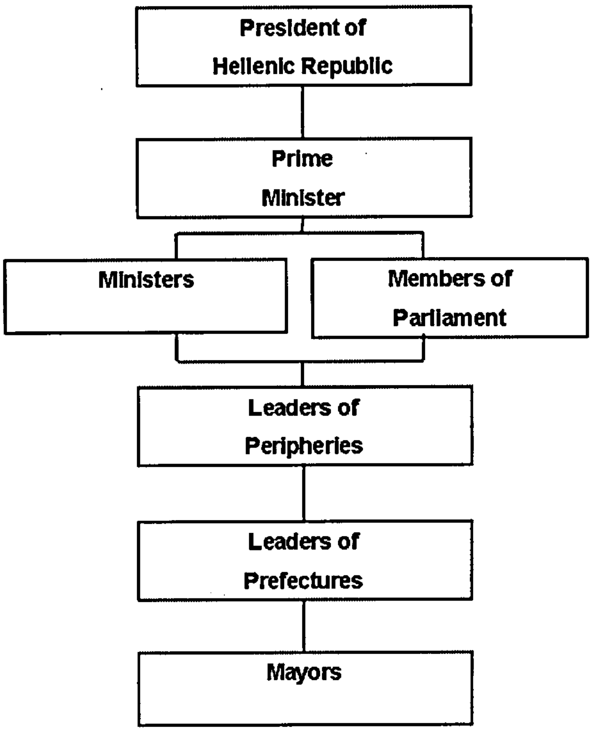


Figure 4.1: Administrative Diagram of Greek Government

In order for the country to achieve a decentralised administration – of all governmental bodies – which addresses the needs of the public located in all the areas of the country and to be more practical to be controlled by the low level management – the central government – Greece is administratively divided into 13 regions, which are called peripheries. Each periphery has its own leader, who is chosen by the Minister of Public Administration and Decentralisation and it consists of a number of smaller areas, which are called prefectures. The total number of prefectures in the country is 51; each has its own leader, who is elected by the local population every four years.

There is also one 'autonomous prefecture called Ayion Oros, on Mount Athos, which is directed by the monks of the monastery' (Hellenic Syntagma, 2000); this prefecture is excluded constitutionally from the Government hierarchy. Except the latter, every other prefecture consists of a number of local communities called cities or municipalities and in total there are 900 cities and 133 municipalities, which are led by elected mayors. The map (Figure 4.2) is the administrative map of Greece, showing the 13 peripheries of the country and the individual prefectures that formulate each periphery.

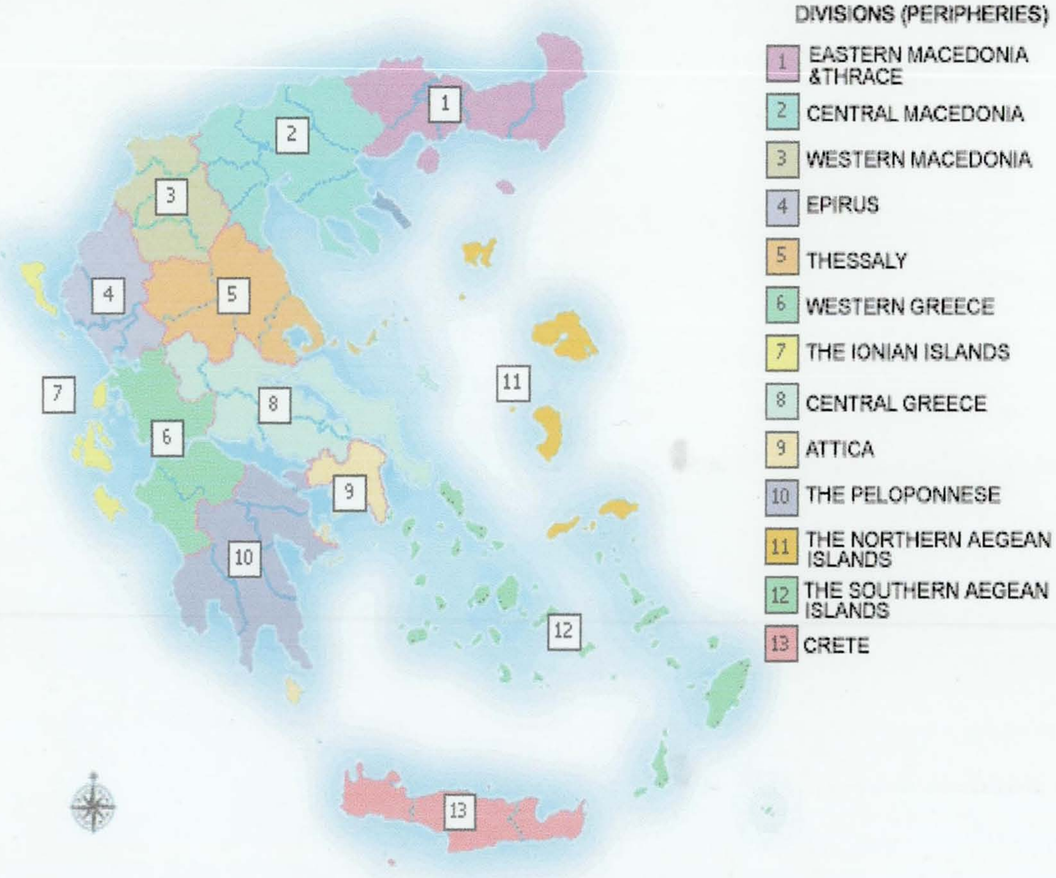


Figure 4.2: Administrative Map of Greece (source: Greek National Tourist Organisation, 2005)

All the peripheries of the country act in line with the bodies of law in order to provide the public with identical services of all governmental organisations. Where it is considered essential, these services must be formulated accordingly in order to cover local needs. The different needs that some peripheries may have are caused by a number of factors including the geographical position, their geological characteristics, climatic differentials and number of population.

Although some peripheries have needed to amend their services accordingly, they all act under the same bodies of law and governmental guidelines. Therefore the examination of one periphery, taken as case study will be used to facilitate the study with the information required. Thus, for the purpose of the present research work the periphery of Central Greece (no 8 on the map) has been used for examination. Figure 4.3 illustrates this periphery along with the five prefectures that constitute it.

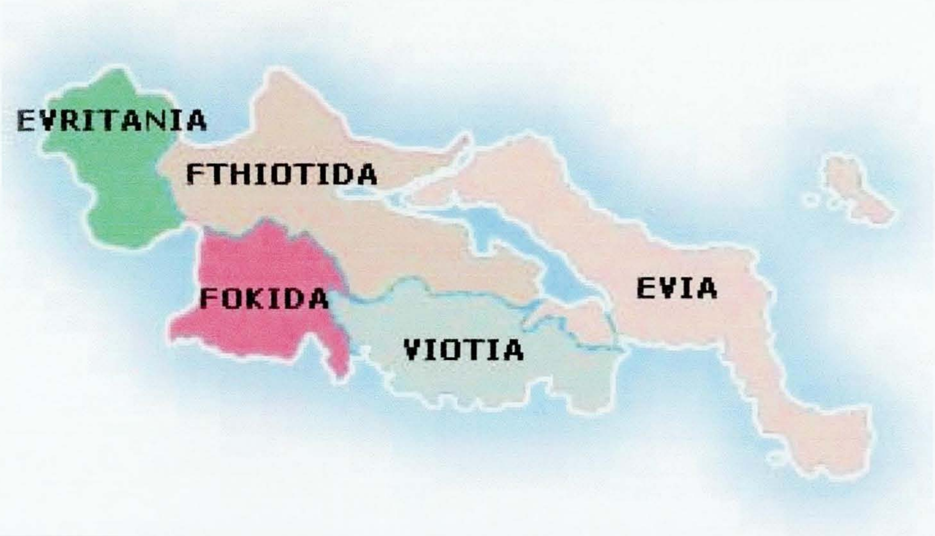


Figure 4.3: Administrative Map of the Periphery of Central Greece (source: Greek National Tourist Organisation, 2005)

The periphery of Central Greece includes five prefectures and these are the prefectures of Evritania, Evia, Fthiotida, Fokida and Viotia. The headquarters of the central administration and the leader of the periphery are located in the capital city of the prefecture of Fthiotida, Lamia. As mentioned in the previous sections, it is essential for the research to achieve a more specific and detailed examination of the administrative procedures of the countries under examination. Therefore, having focused on one periphery, the case study focuses on one prefecture, as all the five prefectures of the periphery of Central Greece act under the same guidelines provided by the administrative body of the periphery. The selected prefecture is Viotia, which along with its municipalities are shown in Figure 4.4. The capital city of Viotia is Levadia, which accommodates the headquarters of most of the major administrative bodies, along with the elected leader of the prefecture.

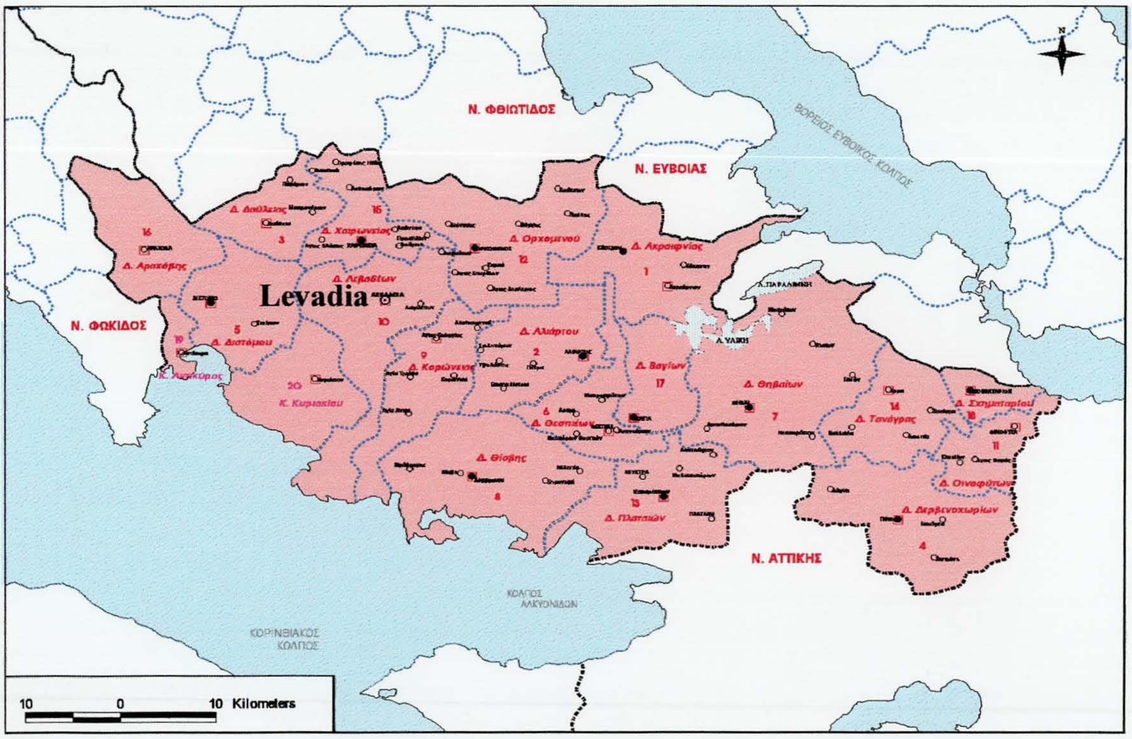
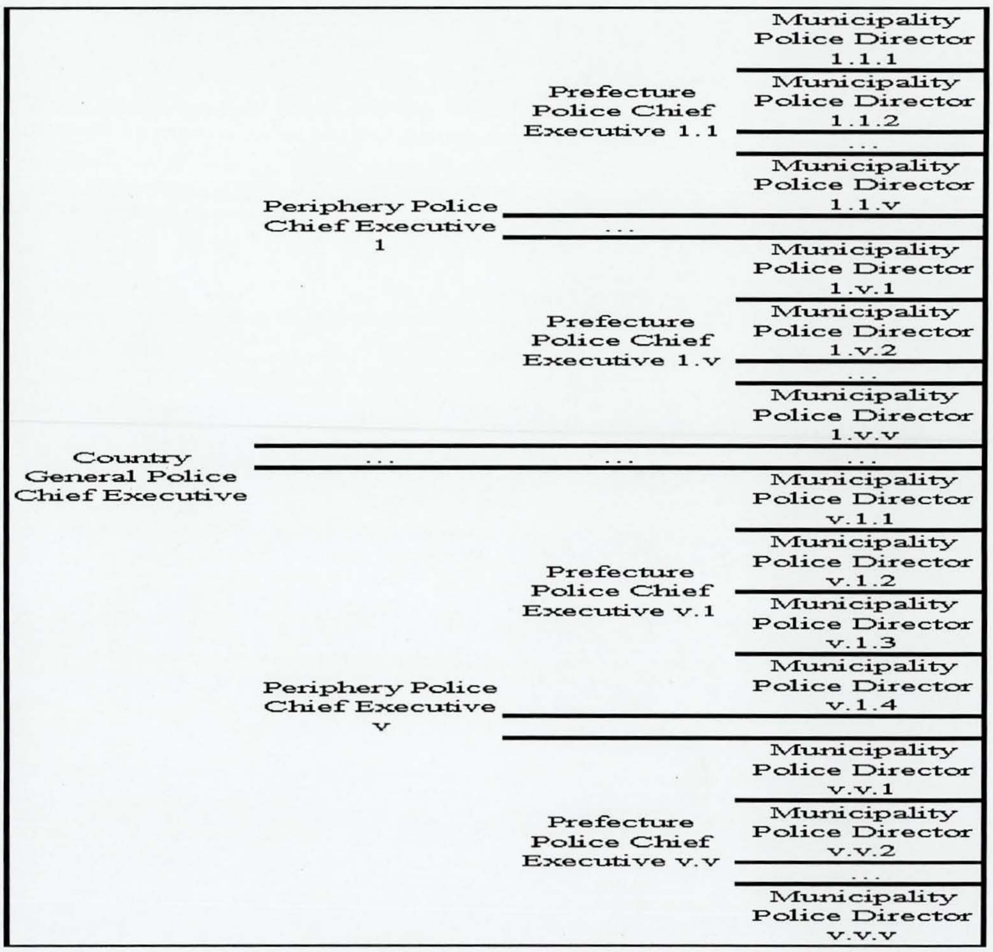


Figure 4.4: Administrative Map of the Prefecture of Viotia (source: Greek National Tourist Organisation, 2005)

The periphery of Central Greece, the prefecture of Viotia and the city of Levadia were chosen because the author has access to the administrative hierarchy and to the regional and local governmental bodies under examination, and therefore this enabled data gathering.

Most of the civil services and governmental bodies of the country follow the same strategy of administrative division. In particular, each organisation consists of the central administration, which is usually located in the capital of the country in order to be in close contact with central government. However, for administrative purposes and in order for the public to be served, there are offices of each department at both regional (periphery) and local (prefecture/municipality) levels. These regional and local departments have their own administration, which is responsible to the next upper management tier. The following paragraph describes the management chain of the organisations, using as an example the body of the Hellenic Police (ELAS).

Table 4.1: Administrative Organisation of Hellenic Police (ELAS)



Each municipality has its own police station with its own resources, including staff and equipment. The director of the local police station is responsible for the effective, efficient and legal functioning of the local station, which in turn is responsible for appropriate delivery of services to the public of the municipality. The police stations leaders of all the municipalities of the prefecture are liable to the chief executive of the police of the prefecture. The chief executive is based in the capital city of the prefecture and along with the chief executives of the other prefectures of the periphery, is liable to the police chief executive of the periphery. This person, along with the leaders of the other local authorities takes decisions referring to local and regional level. In addition to this, chief executives are liable to the general chief executive of the police who is finally liable to the Minister of Public Security. The latter, as a member of the central government, acts with responsibility to the Prime Minister. Table 4.1 is a graphical representation of the above description.

4.5 Case Study 2: The United Kingdom (UK)

The United Kingdom of Great Britain and Northern Ireland is a country located to the northwest of mainland Europe. It comprises the island of Great Britain, the north-east part of the island of Ireland and many small local islands. The UK is surrounded by the Atlantic Ocean, the North Sea, the English Channel and the Irish Sea. It is linked by France by the Channel Tunnel.

4.5.1 Public Administration in the United Kingdom (UK)

According to the Constitution the form of government in the United Kingdom is Constitutional Monarchy. The major administrative divisions of the UK are England, Scotland, Wales, Northern Ireland, the Isle of Man and the Channel Islands (Genuki, 2006). In order for the most accurate and consistent information to be collected and feed the study, the investigation is limited to England. The public administration of the country is organised in national, regional and local level. There is the central government, which is responsible to run the country through the Members of Parliament (MPs), the Ministers and the Prime Minister (PM) – who are elected by the public every four years – and her Majesty, the Queen. The government is the institution that runs the country and it is also known as the Executive.

The government formulates the policies and introduces the legislation in the parliament. Members of the government are usually either members of the House of Commons or the House of Lords. This enables the parliament to keep a check on their work by asking questions or debating the issues. When the results of a general election are known the Queen invites the leader of the party winning the most seats in the House of Commons to become PM and to form a government. The PM is the leader of the government and must be a member of either the House of Commons or the House of Lords. Figure 4.5 hierarchically represents the leaders of each administrative level of UK.

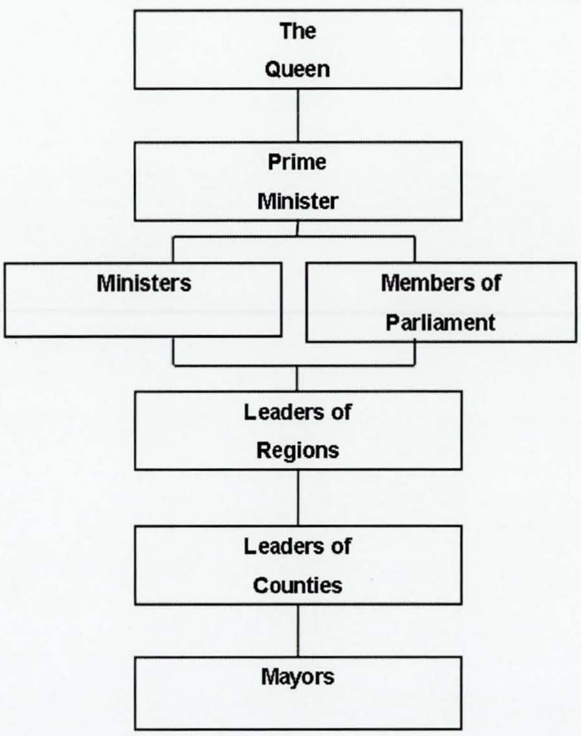


Figure 4.5: Administrative Diagram of UK Government

England is administratively divided into 9 regions and it is further divided into 47 boroughs, 36 counties, 29 London boroughs, 12 cities and boroughs, 10 districts, 12 cities and 3 royal boroughs (CIA, 2006). All the regions of England act in line with the bodies of law to provide the public with identical services of all governmental organisations. However, where it is considered essential, these services must be formulated accordingly to cover local needs. The different needs of some regions may be related to geographical position, geological characteristics and other factors. Figure 4.6 is the administrative map of the UK with particular reference to England representing its regions.

Figure 4.6: Administrative Map of the United Kingdom (source: UK Office of the European Parliament, 2005)

Although each region amends the services offered by the governmental bodies in order to serve the particular needs of the local population these services are still delivered under the same bodies of law and governmental guidelines in order for the services offered throughout the country to be consistent. Therefore the examination of one region as a sample will provide the study with all the necessary information. Thus, for the purpose of the present study the East Midlands region has been taken for examination. Figure 4.7 illustrates this region along with the five counties it consists of.

Figure 4.7: Administrative Map of Region of East Midlands (source: UK Office of the European Parliament, 2005)

The East Midlands region includes the counties of Derbyshire, Nottinghamshire, Lincolnshire, Leicestershire and Northamptonshire. This study is focused on the county of Leicestershire. Figure 4.8 represents this county along with its major cities. The responsible administrative organisation is the Leicestershire County Council located in Leicester, the capital city of the county. Table 4.2 summarises the administrative organisation of the governmental bodies of the two countries under examination.

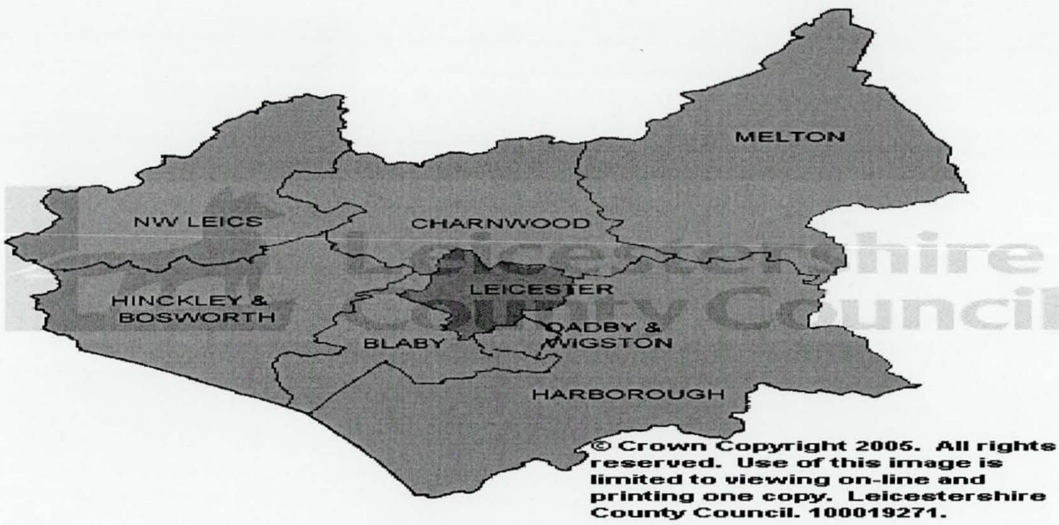


Figure 4.8: Administrative Map of the County of Leicestershire (source: UK Office of the European Parliament, 2005)

Table 4.2: Administrative Organisation of Governmental Bodies in Greece and England

Country	Region 1	County 1.1	Municipality 1.1.1
			Municipality 1.1.2
			...
			Municipality 1.1.v
		...	
		County 1.v	Municipality 1.v.1
			Municipality 1.v.2
			...
			Municipality 1.v.v
	...	...	...
	Region v	County v.1	Municipality v.1.1
			Municipality v.1.2
			Municipality v.1.3
			Municipality v.1.4
		County v.v	Municipality v.v.1
			Municipality v.v.2
			...
			Municipality v.v.v

Most of the governmental bodies of Greece and England, including those responsible for emergency management, follow the above-described model of administrative organisation. The following section identifies these bodies and highlights their contribution to the response phase to an emergency situation caused by a natural catastrophic phenomenon.

4.6 Examination of the Bodies Involved in Emergency Management in Greece and England

The administrative organisation of the two countries under examination – presented in Sections 4.5 and 4.6 – serves as the basis for the organisations of the governmental bodies of the two countries. In particular, bodies relevant to the organisation of emergency management, which are under examination in this research work, follow the same hierarchical flow for their departments. The main organisations involved in emergency management in Greece and England are the following:

- General Secretariat for Civil Protection (Greece);
- Emergency Management Section (England);
- Police (Greece and England);
- Fire and Rescue Service (Greece and England); and
- National Health and Ambulance Service (Greece and England).

These bodies are further presented in the following sub-sections. Other bodies, such as the Environment Agency, the utility services suppliers, volunteer bodies, armed forces and others are becoming involved in the actual operations of emergency response management as operational units, when this is considered essential by emergency management decision makers. However, these parties are not involved in the management of the operations and therefore, they are considered as resources or external experts for the purpose of the present study.

4.6.1 The General Secretariat of Civil Protection (GSCP)

Greece, as described in Section 4.3, is a country that has experienced a variety of natural disasters over the years, including the sudden phenomenon of the earthquake. Among others, floods, heavy snowfalls, landslides and volcanic eruptions have proved catastrophic for the lives of the population of the country, their property and the environment.

Therefore, the government – following the guidelines of the EU – has adopted a holistic approach concerning the management of emergency situations caused by the occurrence of natural catastrophic phenomena. Thus, the General Secretariat for Civil Protection (GSCP) was established under the law numbered 2344, in 1995. This body belongs administratively to the Ministry of Interior, Public Administration and Decentralisation and it is responsible for the 'civil protection and emergency management of all types of natural and technological disasters and other major accidents' (NATO, 2004). This is to say the body for 'Civil Protection aims to the protection of citizen's life, health and property from natural hazards, technological accidents (including biological, chemical and nuclear threats) and other disasters, causing emergency situations during peace period. Based on the above, this scope covers also the protection of cultural heritage, historical buildings and monuments, the resources and the infrastructure' (GSCP, 2006). This is the main aim of the GSCP and it is achieved through the 'responsibility of planning and setting-up the national policy and actions in matters of the prevention, preparation, public information, management and mitigation of natural hazards, technological accidents and emergencies' (GSCP, 2005). The GSCP is the competent authority for all of the disaster management phases: the preparation, the mobilisation and the coordination of civil protection activities; in other words for the mitigation, the preparedness, the response and the recovery phases. The mission of the GSCP in relation to the natural disasters includes the:

- 'Readiness of the personnel and means of CP;

- Elaboration of the available scientific information for the mobilisation of resources in case of emergencies;
- Coordination of response and recovery actions in emergencies;
- Coordination of emergency planning actions at national level;
- Provision of scientific support to the programs, plans and actions in the field of CP;
- Monitoring and control of the Annual National Planning implementation at regional and local level in cooperation with competent authorities;
- Propose the distribution of state funds for CP to the local authorities;
- Preparation of special reports for every major disaster. Revisions, amendment and improvement of existing proposals are included;
- Functioning of an 24/24h Civil Protection Operation Centre (CPOC);
- Operation of a unit for the assessment of information on weather forecasting and other precursory phenomena related with natural hazards, for the early notification and warning of the competent authorities and the general public;
- Public information and awareness;
- Organisation and promotion of volunteer organisations work in the field of CP;
- Cooperation with the competent authorities towards preparing regulations, codes and legislation in the field of prevention. Approval of CP local plans;
- Programming, based on the annual national civil protection planning, of the necessary annual provisions of means and human resources in cooperation with competent authorities;
- Support and promotion (coordination, planning, financing) of the research, education and training in the field of CP;
- Promotion of the country's relations with International Organisations and CP authorities, including representation in International Organisations; and
- Coordination of the assistance provided to Greece and assistance provided to other countries' (GSCP, 2005).

The personnel of the GSCP consist of the administrative personnel, and emergency management team. This includes internal experts, who are mainly responsible for operating the CP Operations Centre on a 24/7/365 basis and collaboration with external scientists, such as meteorologists, chemical engineers, geologists, geophysicists, structural engineers, psychologists, sociologists and others. In addition to these, officers of the fire brigade, the police, the coast guard and the armed forces are responsible for co-operating with the CP in the emergency response operations to disasters. Furthermore, there is the General Secretary for Civil Protection, who leads the GSCP, authorised, among other things, to:

- Coordinate the CP actions during disasters;
- Propose to the Minister the declaration of the state of emergency in case of national scale disasters;
- Declare the state of emergency at regional and local level; and
- Coordinate the assistance provided from abroad.

The GSCP – like the other Greek public services – is organised in three different administrative levels (GSCP, 2004; EC, 2004) namely national, regional and local levels. This means that along with the central body described above, each periphery has its own CP department, which is based in the capital city of the periphery. With the same rationale, each prefecture has a CP unit, which is responsible for all the municipalities of this prefecture.

4.6.2 The Emergency Management Section (EMS)

In the UK the current law concerned with emergency management is the Civil Contingencies Act 2004, which has replaced both the Civil Defence Act 1948 and the Emergency Powers Act 1920. It addresses the contingency planning and emergency management responsibilities of local authorities and other agencies, as well as providing the framework by which the government may invoke emergency powers (Leicester City Council, 2005).

According to the Civil Contingencies Act 2004, the Emergency Management Section (EMS) coordinates each County Council's emergency management department. It works closely with the County's District Councils and other neighbouring local authorities, together with the emergency services, the armed forces, utility companies and local industry, as well as volunteers and voluntary bodies, to ensure that the County Council is well prepared to respond to emergency situations.

The main aim of the EMS is to plan for a flexible approach to all manner of emergencies, enabling the County Council to respond effectively and in a way that is fully integrated with the response procedures of the emergency services and any other partner agency (Leicestershire County Council, 2005). In this respect, the responsibilities of the EMS include planning for disasters, the training and exercising of personnel, as well as the organisation and implementation of emergency response operations. In particular, the main objectives of the EMS are to:

- 'Raise awareness of the need to make adequate preparations for a range of contingencies, and to develop and maintain a range of contingency plans and manuals on behalf of the County Council and Leicestershire's seven District Councils;
- Provide a means of validating contingency arrangements through appropriate training and exercising, thereby enabling the local authorities to provide a swift, efficient, effective and caring response to emergency incidents;
- Provide advice and guidance on all aspects of contingency planning, including service continuity;
- Improve the multi-agency, coordinated response to major emergencies, by drawing relevant people and organisations together through the process of "integrated emergency management"; and to
- Provide the Council's "first point-of-contact" response to emergency incidents, and to provide effective logistic support to our emergency management partner

agencies when required, on a 24/7/365 basis' (Leicestershire County Council, 2006).

The role of EMS during the response phase to an emergency situation caused by a natural disaster includes the coordination and collaboration of all the emergency services and partner organisations involved, as well as the communication of any relevant information related to the actual natural phenomenon, or to the availability and status of resources.

4.6.3 Police

The Police are involved in both the pre-disaster and post-disaster phases of emergency management. The role of the Police in relation to the pre-disaster phases includes cooperation with the other bodies responsible during the formulation or amendment of the national emergency plans. During the response to emergency situations the local Police departments allocate and coordinate their own resources and the leader of the regional Police is responsible, along with the other emergency management authorities' leaders to organise the response operation.

4.6.4 Fire and Rescue Service

The Fire and Rescue Service is also responsible along with the other bodies during the conceptualisation, formulation and adjustment of the national, regional and local emergency plans. This is because fire is a major threat, especially during the summer period, as well as because fire is a secondary hazard following many other disastrous phenomena, as described in Chapter 3 of the thesis. In terms of administrative organisation, the Fire and Rescue Service is also divided into national, regional and local levels, as it follows the organisational model described earlier.

4.6.5 National Health and Ambulance Service

The National Health Service is also organised under the same administrative rationale and it belongs to the Ministry of Health and Welfare. During the emergency situations caused by natural disasters the local personnel, such as doctors, nurses, as well as every other resource (such as hospital buildings, ambulances, medicines and others), become available for the CP department and are coordinated by the President of the local hospital.

The above sub-sections have briefly presented the role and the involvement of the main authorities responsible for the management of emergency situations caused by the occurrence of extreme natural phenomena. A detailed examination of the roles of each emergency service during the response phase takes place in Section 4.9, through the one-to-one structured interview exercises that were conducted with the emergency management stakeholders of Greece and England.

4.7 Emergency Plans for Greece and England

Previous Sub-sections presented the authorities that are responsible for the formulation and amendment of the emergency plans of their countries, as well as being responsible for the effective and efficient application of these plans during emergencies. The following Sub-sections describe the emergency plans of the two countries that have been selected as case studies for this research work.

4.7.1 Emergency Plans for Greece

In the cases of emergency situations caused by natural disasters all the above described authorities need to follow a coordinated, collaborative and interactive procedure and to cooperate in order to provide an effective and efficient response to the event. All their activities need to take place in line with the bodies of law of the country, the ethical issues and the emergency management aims and guidelines. Figure 4.9, is a static representation of the organisation of the emergency response management of disasters in Greece.

Based on Figure 4.9 it could be argued that in Greece there is a common management strategy in dealing with natural disasters across all the administrative levels of the country. However, according to the individual characteristics of each area, such as geographical position, morphology of the ground, population of the area and according to the nature of the catastrophic phenomenon occurring, this strategy could change slightly or moderated, in order to fulfill the particular needs of each individual case.

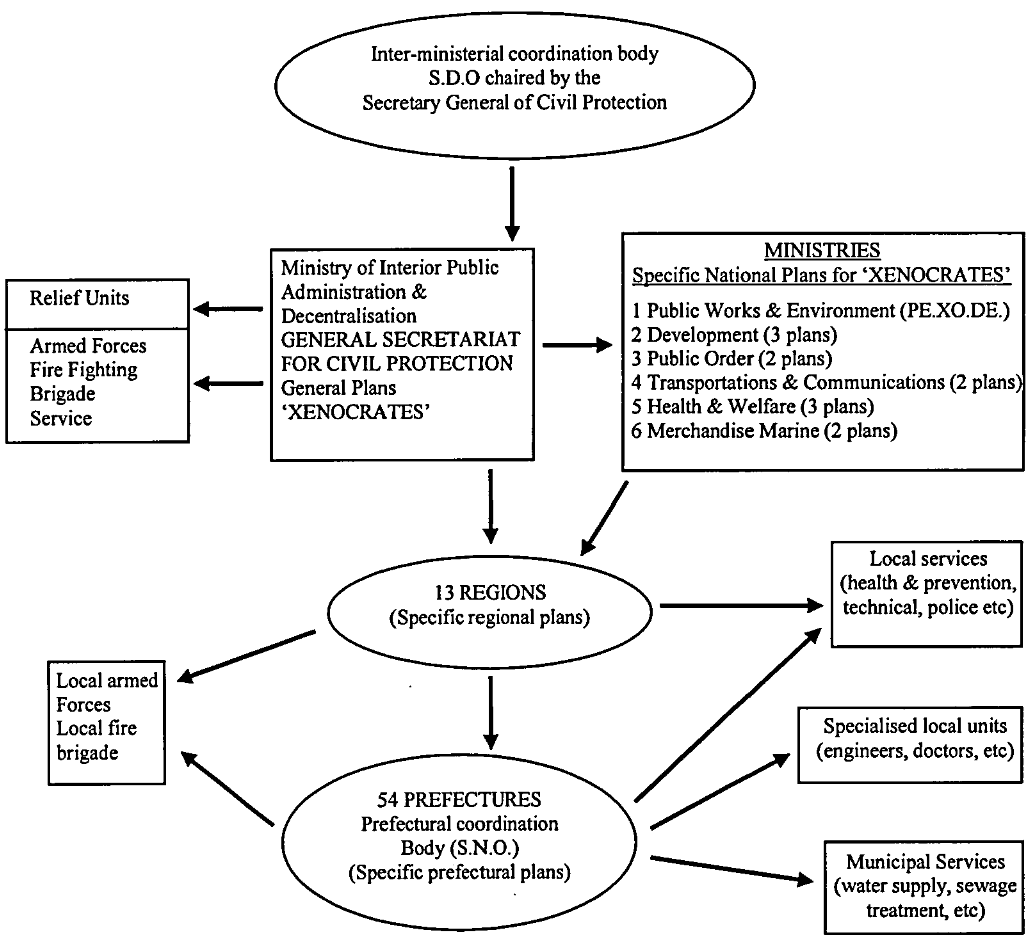


Figure 4.9: Organisation of Civil Protection in Greece (source: European Commission, 2000)

The diagram shows that along with the authorities described in the previous Sections, there is also a body that, in addition to its contribution to the establishment of the emergency plans and the preparedness of the relevant authorities, coordinates them during the response operations to emergencies. This is the Inter-Ministerial Coordination Body (SDO), which consists of a number of Ministries, including the Ministries of:

- Environment, Physical Planning and Public Works;
- Development;
- Health and Welfare;
- Public Order;
- Mercantile Marine;
- Transport and Telecommunications.

The SDO is chaired by the General Secretary of Civil Protection (GSCP) and it coordinates governmental actions in case of regional or major local disasters (CP, 2004; NATO, 2004; EC, 2004). It also 'adopts the annual national civil protection plan, which consists of nation-wide programs and plans of the governmental competent authorities. Reporting on the implementation of country wide measures and actions in case of major disasters is also a responsibility of this committee' (GSCP, 2005). The SDO, along with the GSCP, are responsible for the conceptualisation, as well as the implementation of the overall national emergency plan namely "XENOKRATES", which has been established under the Ministerial Decision numbered 2025, in 1997. This framework provides the relevant authorities and the staff involved in national, regional and local level emergency management with a series of guidelines towards the conceptualisation and application of formal decisions, general guidelines and the relevant bodies of law, which covers actions in the cases of natural and technological disasters and other major accidents.

"XENOKRATES" is updated regularly and every new version is forwarded to the peripheries of the country and through them to the prefectures. The director of the CP department of the prefecture, along with the leaders of the rest of the area's involved authorities, the prefecture leader and the mayors of local municipalities are responsible for the adjustment and adoption of "XENOKRATES" to the specific needs of their area. They also determine the panel which is responsible for the application of

"XENOKRATES" during the response operation to an emergency caused by the occurrence of a natural catastrophic event, including the assessment of information, the decision making, as well as the coordination of the relevant resources and, in general, the coordination and management of the whole response operation. The detailed operational procedures are discussed in Section 4.9. With regard to the mitigation and preparedness phases of emergency management actions, these are initiated by the headquarters of the relevant bodies and they terminate at the local authorities, while during the stage of the response to a catastrophic event the reverse procedure takes place. The local authorities enforce the locally adjusted version of "XENOKRATES", making decisions and coordinating their resources and the whole of the rescue operation. When the situation exceeds the capabilities of the local resources to manage the emergency, the regional plans and authorities are called to support the operation. With the same rationale, the national and international emergency management organisations take part in response operations that demand even further support in terms of resources.

4.7.2 Emergency Plans for England

The whole strategy of management for natural disasters in England is laid on the local authorities and, in particular, on the Regional Emergency Committees as there is no one national organisation charged with formulating disaster plans (EC, 2000; ISDO, 2004). In relation to emergency management the Government has issued "The Standards for Civil Protection in England and Wales", in 1999. 'Although the standards are not a compulsory element of emergency planning in local authorities – the local councils – they are considered to be sound guidance to a comprehensive emergency planning service. Therefore, the standards form the basis of current emergency planning practice' (Gloucestershire County Council, 2000). The local authorities – guided by the government – coordinate the preparation of the emergency response plans. The three levels of the organisation of disaster response operations are Gold, Silver and Bronze, or in other words strategic, tactical and operational levels. These are illustrated in Figure 4.10.

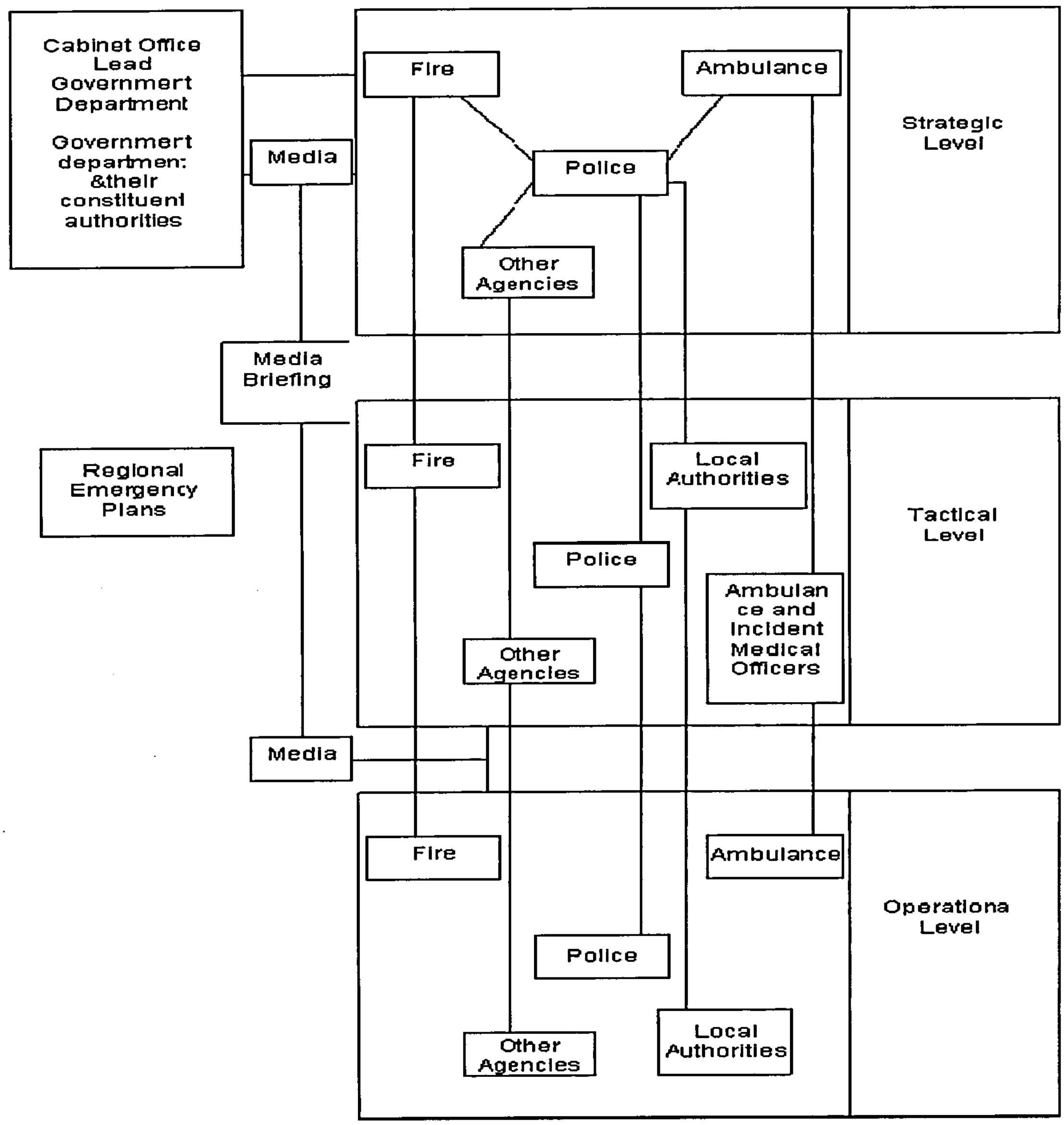


Figure 4.10: Organisation of Emergency Management in England (source: European Commission, 2000)

According to the legislation, the police are responsible for the coordination of the emergency response operations in the case of the occurrence of a natural disaster. In situations when the scale of the disaster exceeds the capability of the local authorities supplementary resources might be called from neighbouring authorities and organisations, as well as from the central government (EC, 2000; ISDO, 2004). In addition to this, the government has the responsibility to request additional relief resources to support the operation from other countries through the EU and NATO.

4.8 Operational Procedures during Emergencies in Greece and England

This section discusses the operational procedures that take place during the phase of response to an emergency situation caused by the occurrence of a natural disaster in Greece and England. It is mainly based on a series of one-to-one structured interviews (see Appendix III) conducted with the stakeholders of the authorities involved in the emergency response phase in Viotia and Leicestershire, as well as on literature review. The interview exercise is the primary research tool of the study and its aim was to identify the general problems, which the emergency management stakeholders face during the response operations, as well as the particular problems related to the use of Information and Communication Technologies (ICT). The following list presents the emergency management stakeholders from Greece and England who participated in the one-to-one interviews:

Greece:

- The Director of the General Secretariat of the Civil Protection Operation Centre;
- The Leader of the Prefecture of Viotia;
- The President of the General Hospital of Levadia;
- The Director of the Fire and Rescue Service of Viotia;
- The Chief Executive of the Viotia Police.

England:

- The Head of the Emergency Management Department of Leicestershire County Council;
- The Director of the Emergency Management Department of the Leicester City Council;
- The Head of the Leicestershire Fire and Rescue Service;

- The Assistant Emergency Planning Officer of the East Midlands Ambulance Service;
- The Chief Executive of the Leicestershire Police Department.

The structured interviews used the same body of questions with minor alterations according to the organisational differences and approaches between the two countries, as these are defined by the government procedures and the bodies of law.

When an extreme natural phenomenon occurs and causes an emergency situation in an area of the country, the local authorities deploy their resources in order to respond to it. As mentioned in the previous Sections, the authorities involved include the Emergency Management unit (CP for Greece, EMS for England), the Police, the Fire and Rescue Service and the Health and Ambulance Service of the municipality, or city.

The prefecture (Greece) or the county (UK), and in particular its leader, acts as the operational leader during the emergency response. When the event is serious and it needs a coordinated response, the leader of the county calls the leaders of the emergency management authorities to a meeting. During this meeting, the situation is assessed, along with the available resources of each organisation, and according to the magnitude of the event they make decisions and take relevant action in order to overcome the emergency situation. The personnel of the authorities involved need to work collaboratively and alongside other profit-making and non-profitable organisations, such as humanitarian bodies, volunteers and charities based on the orders of action allocated to them by the participants of the meeting – the decision makers. Figure 4.11 illustrates the operational procedures, with particular reference to the information flow between the decision makers, the leaders of the operational units and the resources, during the emergency response operations to disasters caused by extreme natural phenomena, which are discussed on this section.

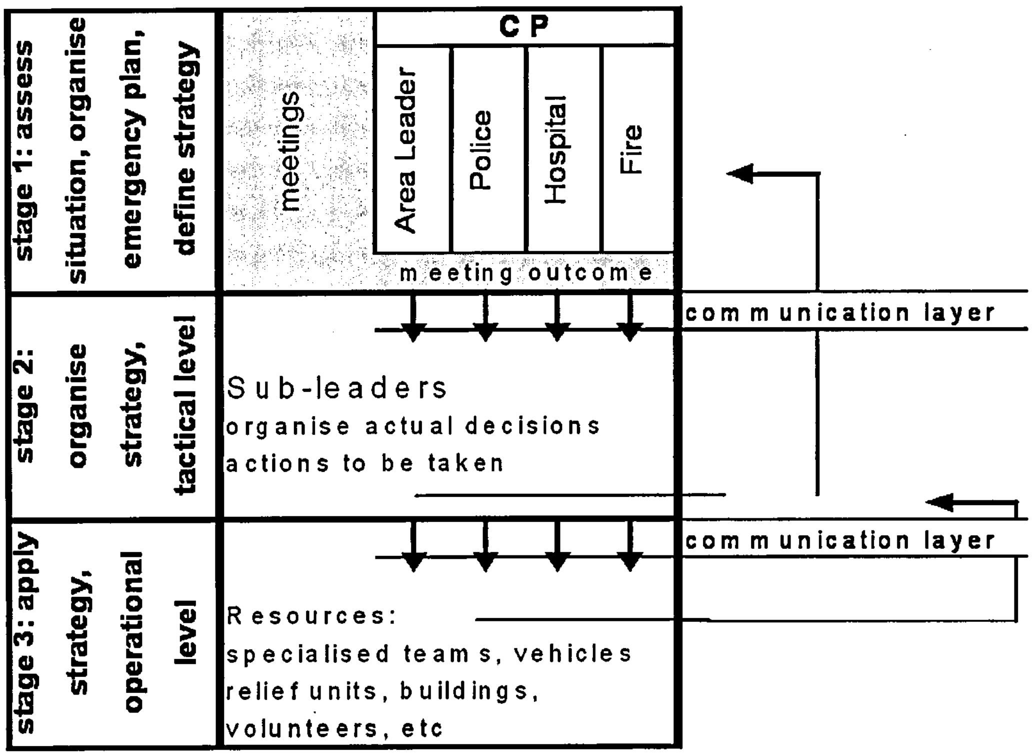


Figure 4.11: General Diagram of Information Flow during Emergency Response Operations in Greece and England

According to the participants of the structured interview exercise, the first information about the occurrence of a sudden extreme natural phenomenon reaches the relevant local authorities through phone calls from the affected people of the area of the occurrence, who are asking for help. Fundamental to all emergency response operations is the identification of the demands that characterise the disaster response environment and the development of the management capabilities required to deal with them (Paton and Jackson, 2002). In order for the demands to be identified, there is the need for a continuous, exact and up-to-date picture of the current situation to reach the decision makers located in the operation centre during the emergency response operation. However, the first images from the affected area reach it through the TV channels' breaking news, or through the oral description of the victims and of the members of the operational units working in the area. The official information about the magnitude of the phenomenon, its nature, the location affected, the development of its dynamics, and the impact of the event reach the headquarters of the Emergency Management unit (GSCP for Greece, EMS for England) from the relevant bodies within the first half hour after its occurrence. The staff of the central body is responsible for providing this information the local EM unit.

An example is the occurrence of an earthquake in Greece. According to one of the interviewees the National Observation Centre (NOC) of Greece needs about 25 minutes in order to collect, analyse and assess relevant data and to provide, using a fax message, the GSCP with exact information about the parameters of the phenomenon. Although the information provided describes the phenomenon according to standard and detailed parameters, these are not in a form that would enable someone to understand and assess the scale of the catastrophe it has caused. Thus, the NOC informs the GSCP that an earthquake with a magnitude of x degrees on the Richter scale has occurred in a particular area, but no one knows if there are any deaths, damaged structures or other catastrophes. In order for detailed and continuous information to become available to the decision makers, and therefore for them to be in a position to organise all the stages of the emergency response operation, the remote operational units of the emergency authorities of the area have to be deployed. Along with their rescue responsibilities, they have to regularly contact the operation centre in order to provide it with a description of the current situation. At the same time the teams receive new orders of action according to the progress of the operation. Information extracted from the interview process shows that the oral route of information transfer is not helpful enough for the decision makers. This is because it is not as accurate as required and, in many instances, people transfer a "picture" that is not objective. This may happen because of stress, personal worry, limited time and in general because of human nature.

Figure 4.12 has been published by the Gazette of the Hellenic Government and it represents the information flow during the response operation to an emergency situation caused by the occurrence of a natural disaster.

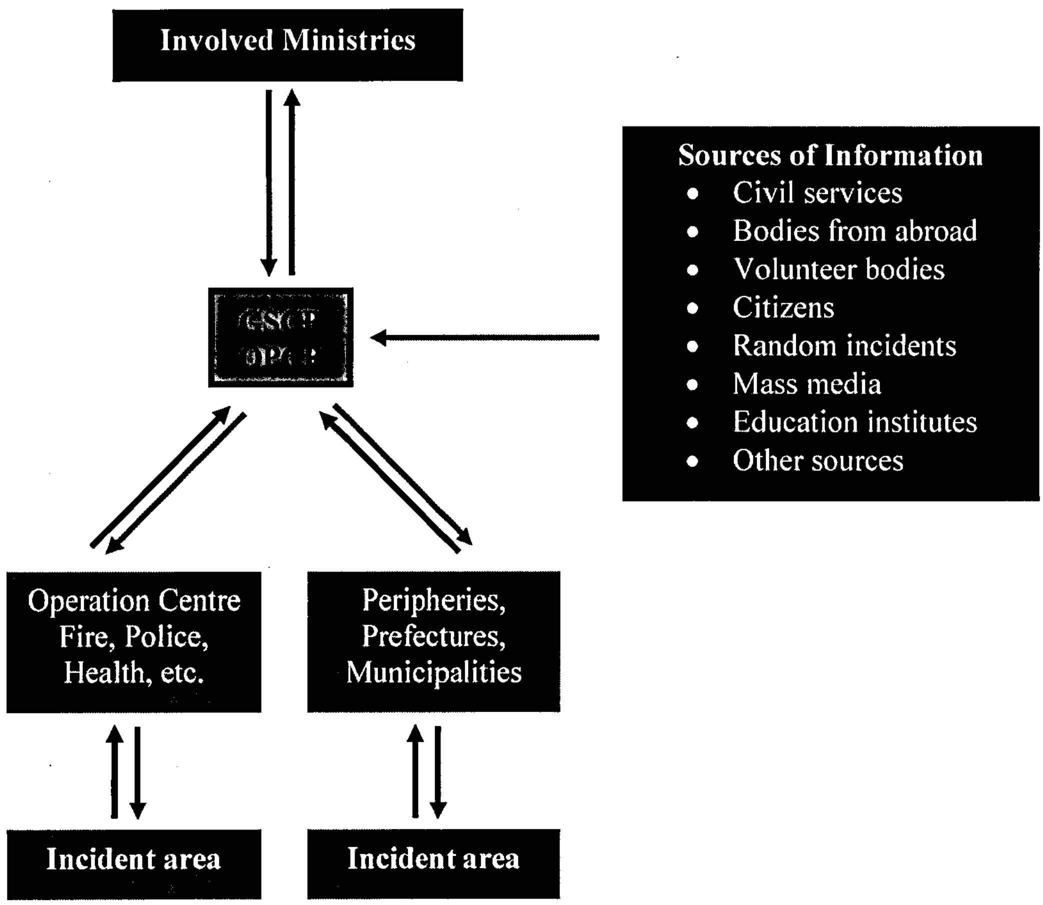


Figure 4.12: General Diagram of Information Flow (source: Gazette of the Hellenic Government, 2003)

During the stages described above in a response operation to a natural catastrophic event, the local authorities, the authorities of the municipality and the county keep the leaders of the equivalent authorities of the neighboring counties informed, as well as the leaders of the region, which are on alert. The leader of the region is responsible for allocating relevant assistance and resources from the neighboring counties if the range of the disaster exceeds the capabilities of the affected area. With an analogous rationale, the leader of the region keeps the neighboring regions and the central administration of the national EMS informed. The latter, along with the Inter-Ministerial co-ordination body (SDO) is responsible for deploying resources from other regions of the country and under the guidelines of the SDO, the PM of the country asks for international assistance, if required. Continuous exchange of information is vital during such operations as the decision makers have to be kept up-to-date at all times with the latest and most accurate information from the area of the incident. At the same time, the operational units have to act as quickly as possible in order physically to save life, property and the environment and assist further in avoiding disruption.

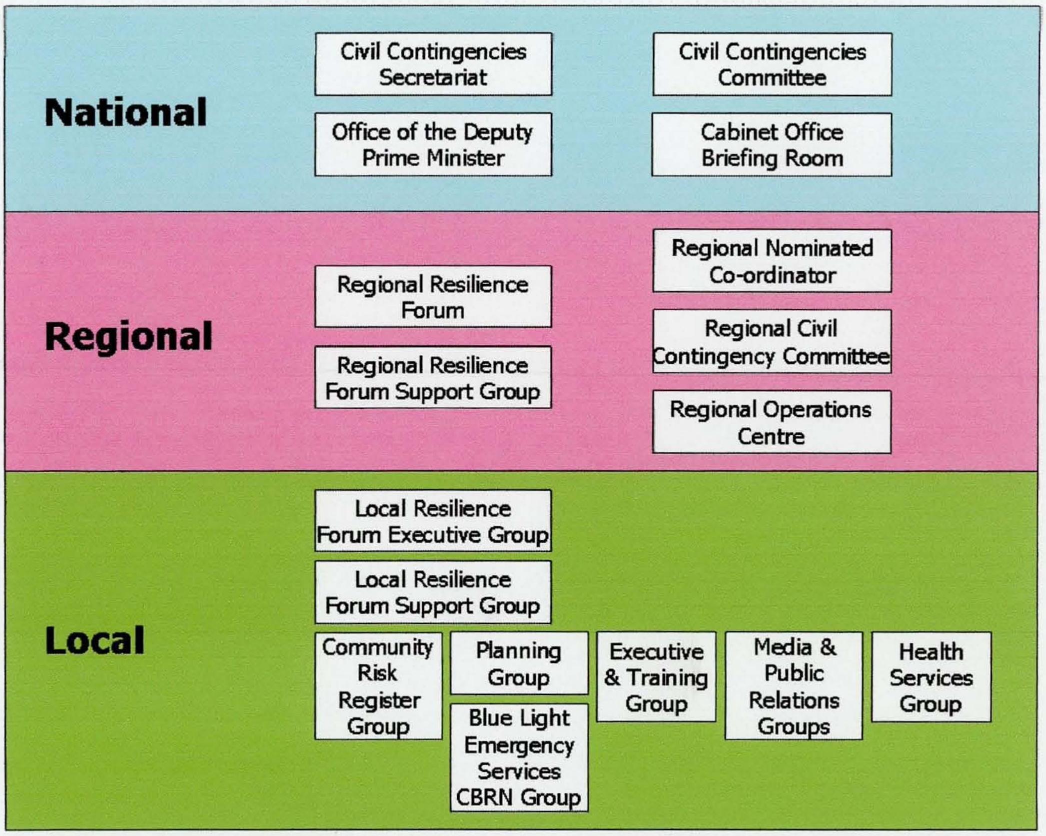


Figure 4.13: Emergency Planning Response (source: Leicester City Council, 2006)

Figure 4.13 is a graphical representation of the authorities involved in the emergency management response operations in England in all three hierarchical levels. This at the same time shows the flow of information between the parties involved in the emergency response operation.

Concluding the description of the operational procedures during the phase of emergency response in Greece and England, it is important to highlight the fact that the whole organisation and application of the operation is human-based. It includes many different professionals and hierarchical levels and expertise from different disciplines. It is characterised as a distributed work environment, where there are many different sources of information, much stress and many different professional involved. It requires timely and accurate exchange of information, and effective and efficient assessment and decision-making processes. Finally, operational actions based on decisions are also considered as a vital component for the successful accomplishment of the overall aim of emergency management, which is to save lives, property and the environment.

4.9 Current ICT in Use in Emergency Response Management in Greece and England

This section is concerned with the findings related to the current use of Information and Communication Technologies (ICT) by the relevant emergency management organisations during the response phase to an emergency situation caused by the occurrence of a natural disaster. The means of communication between each authority's personnel and between the different authorities is presented and their effectiveness, efficiency and the level of satisfaction is analysed. These findings are based on the expert view point of the authorities' emergency management stakeholders who took part in the one-to-one structured interviews.

Based on the interview results, the equipment which the emergency management bodies use with particular reference to the response phase consist of modern computing and telecommunication facilities. Computing facilities include local area networks (LANs), wide area networks (WANs) and geographical information systems (GIS). Telecommunication facilities include integrated services digital network (ISDN) telephone lines, very high frequency (VHF) and high frequency (HF) radio systems, global system for mobile communication (GSM), international mobile satellite communication (INMARSAT) telephones and finally, fax machines. The following Figure 4.14 is a preliminary diagrammatic representation of the operational procedures during an emergency response operation along with the ICT used for the information to pass from one level to the next during the different stages of the operation in Greece and England.

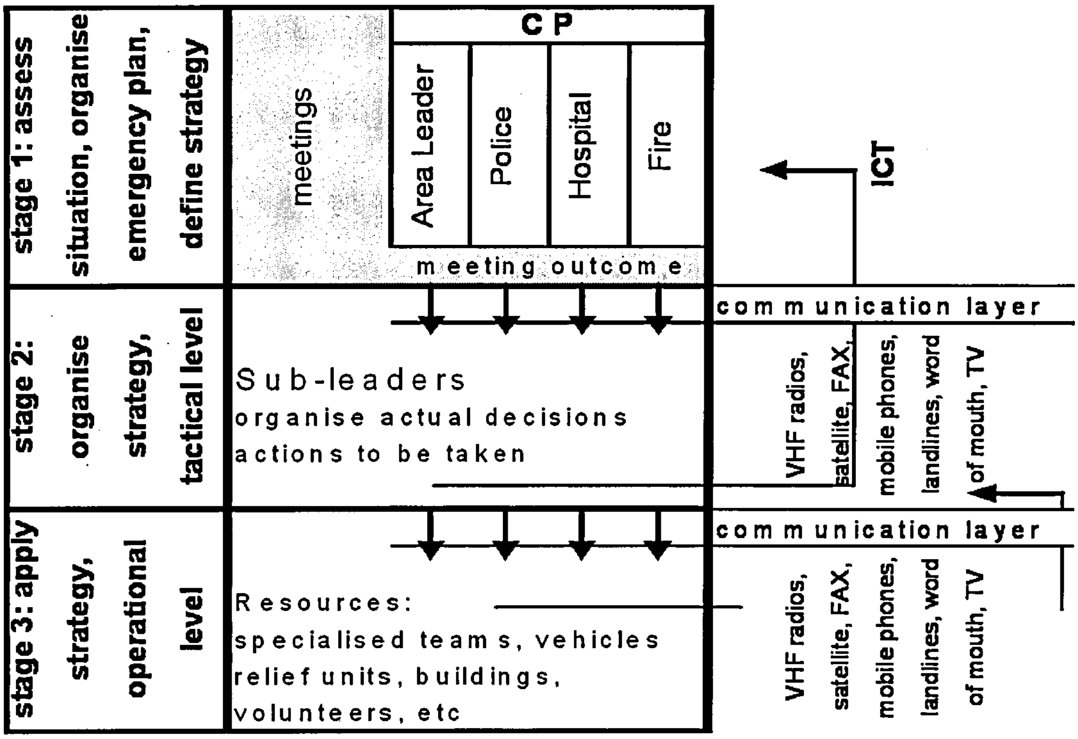


Figure 4.14: Operational Procedures and ICT in Use in Greece and England (source: Asimakopoulou et al, 2005)

In addition to the equipment listed in Figure 4.14, which is located in the central operation centre, there are mobile units as well. These units can be transferred to the area that has been affected by the disaster. They play the role of the "on-site eye" of the operation centre, and the equipment includes satellite communication, GSM communication, videoconferencing, TV receiver and transmitter, video and equipment for collection of meteorological-data and detection of toxic gases. The mobile units provide information about the situation in the area using existing landlines and mobile telephone networks, satellite telephones, and the special networks for wireless communication (VHF) used by the Police and the Fire and Rescue Service. They also provide the decision makers with e-mails containing important information about continuously changing parameters, such as the level of toxic gases, where applicable. The information collected is stored and assessed in the computerised systems of the local emergency management unit, running over LANs and WANs. Based on this information, the leaders of the authorities involved make decisions and give orders to the operational units, in order to be informed about their next steps and the resources available. At the same time, the remote units provide feedback to the operation centre, in order for the participants to propose new decisions about the actions required. Figure 4.15 is a visual representation of the ICT in use during the operation.

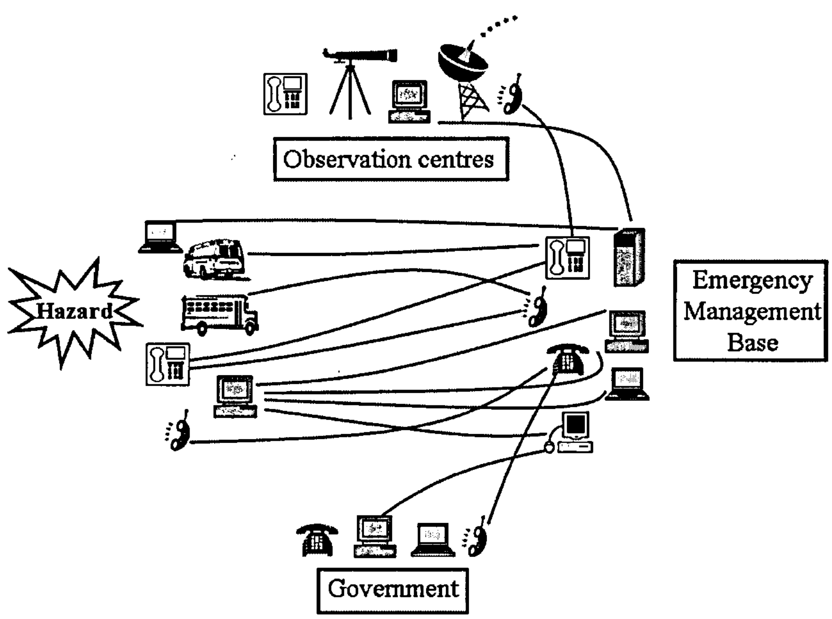


Figure 4.15: ICT in Use during Emergency Response Operations

4.10 Limitations of the Current ICT in Use in Emergency Response Management in Greece and England

As shown in the previous sections, the authorities involved in the emergency management of each country use a range of ICT in order to assess the disastrous situation caused by the occurrence of an extreme natural phenomenon and to respond to it. Science has improved the equipment used to detect, sense, measure and store the characteristics of natural phenomena. At the same time, people witness rapid progress in the telecommunications sector everyday. This section discusses the limitations of the current ICT used by the emergency management authorities, with particular reference to those used during the emergency response operations. In particular, it is focused on the communication between relevant parties, presented above, and on the technological support which the decision makers, operational units and victims have available during an emergency response operation. Findings presented are extracted by the one-to-one structured interview exercise with emergency management stakeholders from Greece and the United Kingdom.

The emergency management stakeholders who took part in the one-to-one interview exercise pointed out that although they operate with the support of the ICT equipment presented in Section 4.10, they often face problems. In particular, they find the current process of meeting at the office of the leader of the operation inefficient. The gathering of the stakeholders is characterised as time-consuming and at the same time they do not have access to their own data. It is believed that if the decision-making process were conducted with the contribution of all the relevant participants, but from their own physical bases and with the opportunity to have access at any time to any important information required, then the whole process would be more informed and therefore more effective and efficient.

Another very important factor that makes the decision-making process even more difficult is that the exact information about the phenomenon reaches the operation centre in no less than 20-25 minutes after the occurrence of the event. During this time, the responsible scientific laboratory collects all the relevant information about the phenomenon, processes it and the exact details are forwarded to the operation centre through fax machines. This time span is considered as important for the meeting participants and hence it may be prove vital for the victims of the occurrence of the catastrophic phenomenon. It has been observed by interviewees that the landline networks, by which the fax machines operate, have been destroyed by the impact of the phenomenon and sometimes they have been overloaded by people trying to find out about the condition of their families, relatives, friends and properties. Apart from the time constraint, this is also considered as another weakness of this process.

A further very important parameter during the response operation is the continuous flow of information between the decision makers and the operational units. In particular, the decision makers assess the situation and make decisions based on the information provided by the operational units and they feed them back with the orders resulting from the decision making process. Therefore, the accuracy of both information channels is considered important for the successful completion of the operation. This information is transferred between the two parties by mobile phones and VHF radios. According to the interview findings this way of transferring information is characterised as inaccurate and insufficiently detailed. This is because it involves a descriptive oral analysis of the situation or the tasks assigned and therefore involves the subjective view of the persons involved, as well as the risk of the lack of some facts due to the limited representation capability of the medium.

In addition to this, the psychological situation of the people involved in this process has to be taken into consideration. Members of the operational units have to overcome much stress and their personal worries about affected family members. It is important to note that the mobile networks used in this process have proved an unreliable communication method in the past as they fail or become overloaded. In turn, VHF radio is the means of communication which the emergency management stakeholders trust the most during the response phase.

The emergency response operations are mainly based on the human and material equipment of the authorities involved in the process. These are known as the resources of each body and they include people, vehicles (ambulances, fire & rescue vehicles, police cars etc.) buildings (hospitals), aircraft and ICT equipment. The decision makers proceed with their decisions according to the situation caused by the event, as well as according to the resources they have available. In order to allocate resources for a particular task, they need to know their current location, availability and working order. Usually, this information is stored in the department of each body in a computer in the form of lists. The relevant staff maintains these lists regularly during their normal everyday activities.

However, the stakeholders interviewed stated that during an emergency operation it is difficult for the leader of each authority to know at any given time what is available, where each one of the resources is located and if the task assigned to it is completed or not. The lack of availability of this piece of information in time may result in a delay, or even prevent resource availability to be taken into consideration for the next task. It is therefore clear that in such instances the emergency management decision makers will most likely not choose a better solution because the narrowed search of the actual problem search space makes it improbable that the better solution will ever be encountered. Concluding this paragraph, some may argue that a real time system where each one of the resources could report the completion of the task, its availability, problems it may have and in general, its status at any time would prove beneficial for the whole emergency response operation. This is because: emergency management leaders would have access to more up-to-date information about the situation, which would enable them to assess the situation in a more informed way. That is to say, the approach would lead them to identify a better solution from their problem search space.

Finally, another major assumption is that the operation centre and its equipment will remain intact during the disaster. In situations where the operation centre is affected by the catastrophic phenomenon and it cannot serve as the base of the meeting of the decision makers, they erect a mobile construction where they can organise the operation. This procedure is also time-consuming and the operation has to be organised without technical equipment and relevant documentation.

Overall, the limitations of the current ICT in use by the emergency management stakeholders during the response operations are summarised in Table 4.3.

Table 4.3: Current ICT Limitations During the Emergency Response Operations

Current ICT Limitations during Emergency Response Operations
Gathering of stakeholders to a centralised place is time consuming;
Centralised store of important information;
Gathering of stakeholders to a centralised place limits access to individuals' centralised resources/data;
Non-timely exact information about the phenomenon;
Not exact information about available resources;
No real-time pictures;
Failing of telephone networks; *Overloaded telephone networks;* *Possible computer network failure;*
Incompatibility of computerised means of communication.

Section 4.11 was concerned with the limitations of the current ICT in use by the emergency management authorities during the response operation to a catastrophic event. These limitations are taken into consideration in the following chapter of the study, Chapter 5, where a conceptual model is proposed with main focus of improving the coordination, collaboration and communication of emergency management stakeholders during emergency response operations to natural disasters.

4.11 Summary

This chapter has presented a review in relation to Objective 2 of the study. In particular, two member states of the EU have been examined as case studies. These are Greece and the UK. Through these case studies the organisational procedures of the authorities responsible for emergency management have been presented and the effectiveness and efficiency of the current ICT in use during the emergency response operations to natural catastrophic events have been assessed. The aim of this chapter has been met with the support of a primary research tool (one-to-one structured interviews), which conducted with emergency management stakeholders, representatives of the two countries under examination. Findings from this method suggest that there are a number of limitations with the current ICT in use by the emergency management authorities.

Further to this, findings have led to identification of the need of a distributed computerised environment, which will embed the current operational procedures and the current ICT in use; it will support decision makers, as well as operational units, during the phase of response to an emergency operation caused by a natural disaster. Finally, it has been concluded that such an approach could allow emergency management decision makers to identify a better solution in order to manage the current situation from a wider search area. To this end, the aim of Chapter 5 is to integrate all primary and secondary research findings using Soft Systems Methodology (SSM) in order to develop a conceptual model able to support emergency management stakeholders towards more effective and efficient emergency response operations to natural disasters.

Chapter 5 The Soft Systems Methodology (SSM) Conceptual Emergency Response Model (ERM)

5.1 Introduction

This chapter is concerned with the analysis and investigation of the problems identified in Chapter 4. In particular, it addresses them by using Soft Systems Methodology (SSM). This involves the presentation of the problems and conflicts that take place during the process of emergency response using SSM epistemology. It continues by presenting the process by which the results of the primary findings can be integrated via the methodology into the development of a generic conceptual communication and information model for emergency response management of natural disasters. The proposed model has been described, as well as compared with the real world, in terms of the existence of its activities and processes, the ways in which they take place and the level of effectiveness, efficiency and satisfaction they provide to the emergency management stakeholders during response operations to natural disasters.

5.2 The Application of SSM in Emergency Response Management

The following sub-sections present the application of the SSM epistemology to the problem area of the study.

5.2.1 Overview

The aim of Chapter 5 is met with the detailed application of the SSM tools – as these have been reviewed in detail in Chapter 2 – to the problem area under examination. In particular, this chapter uses a Rich Picture, to visualise and describe the problem situation and it continues with the Analysis of the Intervention (Analysis One), the Social System Analysis (Analysis Two) and the Political System Analysis (Analysis Three). It employs the Relevant Systems tool to focus on the human activity within the problem situation and it derives with the Root Definition and CATWOE, which lead to the formulation of the proposed conceptual model. The chapter continues with the detailed description of the model and finally, compares it with perceived reality in terms of whether the activities of the model exist or not in the real world, in what form and in what systems they exist and whether the activities that exist are good or bad.

5.2.2 The Rich Picture

Based on the case studies (Chapter 4) and the literature review (Chapters 2, 3 and 4), as well as on the findings from the one-to-one structured interview exercise conducted with emergency management stakeholders form Greece and England, discussed in Chapter 4, a Rich Picture has been produced in order to visualise, explore and further exemplify the problem situation. In particular, it describes the processes in which relevant stakeholders, decision makers, leaders of the involved authorities, operational units and victims communicate their decisions, problems and/or orders during the response phase of an emergency situation caused by a natural disaster. The Rich Picture describes the conflicts and communication breakdowns during this process. It also includes the operational and communication instruments that the parties involved use during the emergency response operation.

Moreover, the Rich Picture highlights the operational procedures taking place between various individuals and/or operational units during the response phase of an emergency situation that is caused by a natural catastrophic phenomenon. These are shown as interaction flows in Figure 5.1. Segments as shown in the Rich Picture above, indicate that stakeholders as individuals and/or operational units may belong to a different level. That is to say, locals may need to interact with other individuals and/or operational units from the same county and/or from another region in the nation depending on the scale of the disaster and resource availability.

Similarly, Figure 5.1 shows a number of local and/or regional processes that are undertaken by individuals or operational units. These processes are no more than interactions between emergency management stakeholders but most importantly, these may include operations that could be manifested in a more effective and/or efficient manner. In the SSM epistemology these are called conflicts, illustrating that there is room for improvement, and they are represented in the form of scissors. On this basis, the Rich Picture graphically represents and exemplifies the situation drawing evidence found in the structured interviews with the emergency management stakeholders, discussed in Chapter 4. Findings are directly relevant to the administrative organisation and the emergency response management application for both Greece and England.

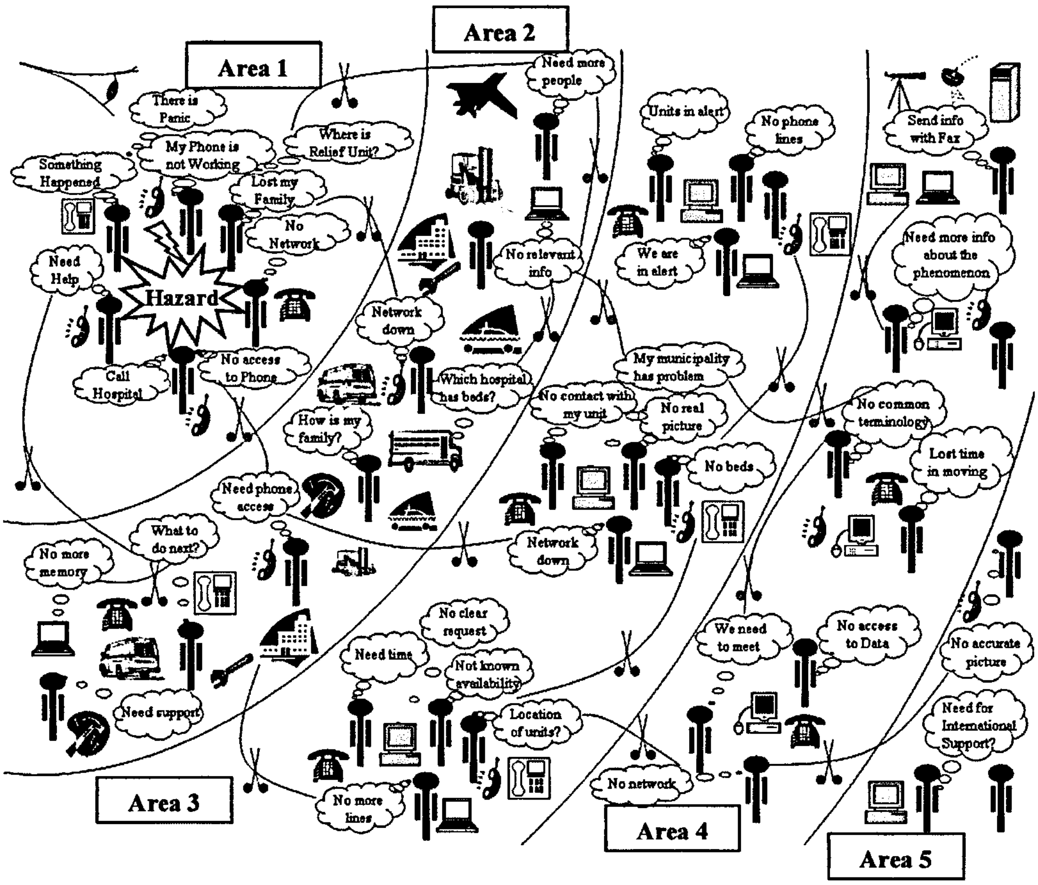


Figure 5.1: The Rich Picture illustrating climate within the Emergency Response Management

The Rich Picture has been segmented into five parts. Area 1 as the first segment shows the area affected by the occurrence of the disaster, whilst Area 2 shows potential resources required for tackling the situation. It is important to note that all resources are owned by the nation and they are distributed for use in each county. It is anticipated that there may be a requirement for utilising resources that are not available locally. Organisationally, local services have the authority to make decisions regarding the use of available local resources only. That is to say, when the requirements for resources exceed the availability of local resources, local authorities need approval from a regional authority for the use of neighbouring counties authorities' resources. Similarly, regional authorities need to seek and receive approval from the national level (ministry) for use of neighbouring region's resources. On this basis, the remaining three segments namely Area 3, 4 and 5 show response phase related decisions and operational actions on a local (Area 3), regional (Area 4) and national (Area 5) level. The foundations for the operation as a whole are the effective and efficient collaboration, coordination and communication of the distributed decisions and resources – both human and mechanical ones, at all three hierarchical levels of the country.

Based on findings discussed in Chapter 4, the Rich Picture illustrates a number of conflicts related to the communication processes between the victims and the operational units, between the members of the operational units, as well as between the leaders of the authorities, who need to make decisions and provide appropriate solutions. It is important to recall that the decision makers have to manage the emergency situation, following at the same time the organisational administration and the hierarchy of the government bodies of their country. Conflicts shown are also related to the means of communication used to support the decision-making and operational procedures during the emergency response phase.

In particular, the Rich Picture illustrates the area of the disaster, where the victims, as shown in Area 1, are seeking help. Victims may try to communicate with the local authorities through landline and mobile networks that, according to the findings, are not always available. According to the natural phenomenon that has occurred, the level of the emergency, the disruption it has caused and the location of the occurrence, the victims sometimes have no access to communication means (such as telephones, see Area 2) to ask the relevant authorities (see Area 3) for help. At other times, after the occurrence of a catastrophic event, although they may have access to telephones (landlines or mobile) the networks may either be destroyed or overloaded from people trying to find out the situation of their relatives. Therefore, it is not always easy or even feasible for the victims to use these communication means. Another very important factor at this level is that affected people are not always capable of communicating because of their situation. They may be too seriously hurt or stressed to provide the operational units with relevant information about their location and situation. Area 3 of the Rich Picture represents the bases of the local authorities, including the Civil Protection (CP) or the Emergency Management Section (EMS) (according to the country), the city council, the fire and rescue service, the police and the health and ambulance service of the affected area. The leaders of these authorities may use the same communication means with the victims in order to communicate with them. In addition to these, authorities and their operational units use a series of computer-based instruments to communicate with each other and with their own resources, located in Area 2.

Area 2 represents the resources of all the authorities involved in the emergency response operation, human and mechanical, which are employed to try to rescue the victims, following the decisions for action of their leaders. However, these people are the "eyes" of the authorities in the area of the disaster, as they feed their bases with information about the current situation. Area 4 illustrates the same authorities as Area 3, however, at regional level and Area 5 in national level. As described in Chapter 4, in order for local authorities to operate outside their administrative borders, they need the approval of the regional ones and these need the approval of the national ones. There are also many communication breakdowns between the authorities involved in emergency response operations at all the hierarchical levels due to ICT failures. The conflicts in the communication make the decision making process, as well as the identification and allocation of available resources and the actual response operation difficult and costly in term of time, money and most importantly, in terms of human lives.

Findings from the one-to-one structured interview exercise also show evidence that it is always difficult for the decision makers to see the whole of the picture in relation to the situation concerned. This includes the difficulty for decision makers to coordinate distributed resource availability and therefore, to know at any time the status of a particular situation, including the status of a particular operational unit that has been assigned the execution of a particular job. These limitations have been described in Chapter 3 when presenting Simon's "bounded rationality" theory. Additionally, according to the emergency management stakeholders, the communication breakdowns occurring during the emergency response operation make it ineffective, and they cause the chaotic situation presented in the above Rich Picture. In turn, ICT breakdowns, lack of knowledge of what resource is available, as well as access to dated and/or obsolete information in relation to the current concerned situation leave emergency management decision makers to try to identify a solution from a search space that either does not reflect the reality, or it is far smaller than in reality, which ultimately decreases the opportunities for a better solution to be encountered.

The following sections of this chapter apply the SSM analysis processes to the particular problem area, utilising all the elements extracted from the literature review, the case studies, and the interview exercise (presented in Chapter 4) in order for the Root Definition and CATWOE to be determined, which will lead to the production of a relevant conceptual model with a particular reference to the emergency response operations to be established. That is to say, the conceptual model produced aims to provide a representation of the minimum activities required for a more effective and efficient management of response operations during emergencies caused by natural disasters. It is worth noting that the model does not try to change the processes the authorities currently use, but to organise them in a more effective and efficient way. Hereafter and based on the findings described in Chapter 4, effectiveness will refer to the quality of 'doing the right things' (Wikipedia, 2007) including the identification of available and appropriate resources to be used for decision-making purposes and/or operationally-based actions. Specifically, effectiveness will refer to the identification of the appropriate resources from a pool of available dispersed resources in order to control, coordinate and communicate them for decision-making and operation purposes. Similarly, efficiency will refer to the optimisation of doing things right, including the swiftness of making the best possible decision for a particular situation and acting appropriately.

- **The problem**

Summarising, the problem area of the present research work is related to the current use of ICT during emergency response operations for natural disasters. In particular, the limitations of ICT, in providing seamless access to dispersed resources in order for emergency management stakeholders to control, coordinate and communicate their resources and processes. Other problems include resource incompatibility, ICT failure, no real-time and accurate information and the absence of automated solutions. These result in inadequate support to the emergency management stakeholders.

5.2.3 Analysis One: Analysis of the Intervention

The Analysis of the Intervention examines the intervention itself and describes who occupies the three specific roles in the intervention. These roles are the Client, the Problem Solver and the Problem Owner. These are discussed next.

- **Client**

A client is referred to as the person who commissioned the study (Horton, 1999). Therefore, for the purpose of this study the client is the author, as she is the one who committed to undertake the study. Therefore, in her own right, she may be responsible for causing some intervention. However, the author's inspiration and aspiration as the client of this study is based on the need identified in the secondary and primary research tools, including findings from the literature review, case studies and interviews. This is to improve communication between the authorities involved in the emergency response operation when a natural disaster occurs in an area, in order for the losses related to the potential victims, property and the environment to be minimised. To this extent, the author is the client of this study.

- **Problem Solver**

Checkland and Scholes (1999) describe the problem solvers as all those people who are going to conduct the study, including all those who wish to do something about the problem situation and are prepared to support the study by making resources available. Within the context of the present study, the problem solvers include the researcher and her environment in terms of the available resources, methods and tools. These include the emergency management stakeholders of Greece and the UK, the subjects of the primary research tool, the supervisory team, feedback from conference audiences when presenting work in progress, the libraries and in general the university resources used.

- **Problem Owner**

'In terms of the question who has a problem in this situation' (Checkland and Scholes, 1999; Horton, 1999), it is the members of the emergency management authorities involved to the emergency operation of the response to a natural disaster, as they are facing the problem of communicating their decisions and needs in an effective and efficient way. However, although, in the first instance, this seems to be the answer, the truth is considerably different, as the real problem owners are the victims of the occurrence of a catastrophic event, including people, property and the environment, as they could not be rescued in a timely fashion.

5.2.4 Analysis Two: Social System Analysis

Analysis Two focuses on the social system in the problem situation and analyses the roles, the norms and the values inside this system. These are captured in the following paragraphs.

- **Roles**

The role of the emergency management stakeholders is to meet the aim of emergency management, which is to save lives, property and the environment. However, all relevant actions need to be undertaken following a series of processes and policies, such as the ethics and the bodies of law of the country including the organisational hierarchy between emergency management stakeholders and the authorities to which they belong.

- **Norms**

It is expected that emergency management stakeholders employ a series of actions to minimise loss during an emergency situation caused by a natural disaster. To achieve this, stakeholders need to take actions in the form of decisions and/or to carry out appropriate assigned operational tasks. They have to be aware of and operate under the ethics and the bodies of law and policy of their authority and country, which secure their decisions and actions. They must also operate using examples drawn from relevant past practice and/or experience. Most importantly, they must be aware of the availability of relevant resources, as well as have access to the best possible up-to-date and accurate picture of the current emergency situation and any other relevant data related to the natural phenomenon that caused the emergency. It is anticipated that such action will help assist them in making an informed decision and/or act appropriately throughout the whole emergency response operation.

- **Values**

The commitment required from the stakeholders involved in emergency response management operations to save lives, property and the environment determines the level of effectiveness and efficiency of accomplished actions. That is to say, the value of the emergency management stakeholders can be measured from the level of "doing the right thing" and "doing the thing right" as a result of making an informed decision and/or acting appropriately. This involves the need for keeping and maintaining an attitude in relation to making informed decisions and taking appropriate actions in a timely fashion. This clearly identifies the value of communicating relevant unprocessed data, decisions made and decisions of actions to the other related parties. This means that making information available and accessible to relevant parties in the most effective and efficient way possible could further assist in the application of their expertise to save lives, property and the environment.

5.2.5 Analysis Three: Political System Analysis

It is expected that people involved in emergency management should realise that the result of their involvement is a commodity, which gives them power within the group that is interested in this particular activity (Checkland and Scholes, 1999). In relation to the emergency management decision makers the disposition of their decisions and order of actions are the means of their power and, because this depends on whether or not they are able to communicate these to the relevant parties involved, there is nothing to guarantee their power. Similarly, other people involved in emergency response operations, such as operational units are dependant on the disposition of the orders of action assigned by decision makers, as well as being dependent on whether or not they are able to receive orders from decision makers. For example, ICT breakdowns may not allow operational units to receive relevant orders. The disposition of reporting back to the decision makers regarding the accomplishment of their assigned task is the operational unit means of power.

Clearly, ICT breakdowns can cause communication disruption and therefore, there is nothing to guarantee their power. Overall, the power of each individual or party within the group depends upon the ability of all of the involved emergency response individuals and parties to communicate their data, information, decisions, orders, needs and actions in the most possible effective and efficient way. To this extent, the nature of the power embodied in communicating relevant information during the response to an emergency has the ability to:

- Alert relevant emergency management authorities to the occurrence of a catastrophic natural phenomenon;
- Collect and assess information about the natural phenomenon;
- Collect and assess information about the disastrous situation (i.e. disruption caused by the occurrence of the phenomenon);
- Report to relevant authorities/stakeholders of what is required;
- Inform decision makers about availability of resources;
- Store relevant data towards the assessment of the situation and for future reference;
- Support decision makers during their decisions making process;
- Provide operational units with orders of actions;
- Take relevant actions;
- Allow operational units to report their status.

5.2.6 The Relevant Systems – Worldviews

This section is concerned with either naming the human activity in relation to the problem situation or by focusing on the issues, problems and conflicts within the problem situation. The two ways of naming relevant systems are the Primary Task System and the Issue-Based Relevant System, which are discussed in the following paragraphs. Primary findings, as discussed in Chapter 4 and illustrated in the Rich Picture, have been used to identify the following.

- **The Primary Task System**

Communicating relevant information during the response phase of emergency management is based on the need of the stakeholders to be fully informed about any new information and any changes that are relevant to their task in order to assess and make decisions of action as appropriate. Furthermore, operational units need to receive orders of action and report the status of their action back to the decision makers. Moreover, communicating relevant information is based on the need that even though many different disciplines are involved during the process, they have to work both as individuals, as well as an entity in order to achieve the aim of the emergency management.

- **The Issue-Based Relevant System**

Improving the accessibility and availability of data, decisions, orders of action and in general, improving the communication of relevant information during the emergency response phase to the occurrence of a natural disaster is an important asset. This is achieved by providing a more effective and efficient method for all people involved in the process, including decision makers and operational units to take more informed decisions and act appropriately. This will make them aware and keep them up-to-date with what has happened, what needs to be done, how, when, where and by whom, so they are fully informed of the current situation.

5.2.7 The Root Definition and the CATWOE

The following sub-sections present the Root Definition and the CATWOE, which have been identified towards the formulation of the conceptual model, which aims to improve communication between emergency management stakeholders during the emergency response operation to the occurrence of a natural disaster. The Root Definition and the CATWOE are defined in relation to the Issue-Based Relevant System described earlier and they are presented below.

- **The Root Definition**

According to SSM the Root Definition of a problem includes 'verbal definitions expressing the nature of purposeful activity systems regarded as relevant to exploring the problem situation. A full root definition would take the form: do *X* by *Y* in order to achieve *Z*' (Checkland and Scholes, 1999). Thus the root definition of the problem area for the present study stands as:

  - A system owned by the emergency management and the other authorities directly involved when a natural disaster occurs, to assist in emergency response operations (*X*) by improving the effectiveness and the efficiency in terms of controlling, coordinating and communicating the emergency management procedures and the relevant resources (*Y*) in order to save lives, property and the environment (*Z*).

- **The CATWOE**

The root definition presented above can be summarised by the following CATWOE (where C: customers, A: actors, T: transformation, W: worldview, O: owner and E: environmental constraints). The CATWOE is the mnemonic acronym for: who is doing what for whom, to whom are they answerable, what assumptions are being made and in what environment (Smyth and Checkland, 1976):

C: Emergency Management Body and all the authorities involved, but primarily the potential victims of a natural disaster, as they are the beneficiaries of all response efforts;

A: Emergency Management Body and relevant authorities, either as decision makers, coordinators, operational units or as victims;

T: Need for a system to provide more effective and efficient control, coordination and communication of relevant resources when a natural disaster occurs -----► Need met;

W: The system's T will assist in saving lives, property and the environment and therefore it will provide potential victims and emergency management stakeholders with stability and confidence;

O: Emergency Managers, authorities involved, operational units and potential victims;

E: Parties involved in the operation and the disaster circle, including sets of policies, ethics, the bodies of law and others.

According to SSM epistemology, the next step is to explore what should happen in the system in order for the requirements described in the root definition and the CATWOE to be achieved (Skidmore and Eva, 2004). The model used for this is called the conceptual model and it is formulated and presented next.

5.3 The Conceptual Emergency Response Model (ERM)

The following sub-sections are concerned with the conceptual model.

5.3.1 Integration of Findings

This sub-section involves developing the root definition's conceptual model by expressing with verbs the relevant activities necessary to carry out the transformation (T) within the other constraints of the model. The model involves the integration of all the literature review and interview-based findings within the SSM approach as described earlier, which includes the following:

- Rich Picture;
- Analysis One, Analysis Two and Analysis Three;
- Primary Task;
- Root Definition; and
- CATWOE.

Specifically, literature review and interview-based findings point out that the county's leader acts as the operational leader during the response phase when a natural disaster occurs. When the event is serious and it needs a coordinated response, the leader of the county calls the leaders of the emergency management authorities to a meeting. During this meeting, the situation is assessed, along with the available resources of each organisation and according to the magnitude of the event they make decisions of action. The personnel of the involved authorities try to work as teams along with other non-profitable organisations, such as humanitarian bodies, volunteers and charities based on the orders given by the participants of the meeting – the decision makers.

It has also been found that fundamental to emergency response is the identification of the demands required to assess and tackle the situation appropriately. Continuous exchange of information is vital during such operations, as the decision makers have to be always kept up to dated with the latest and accurate information from the area of the incident. In order for detailed and continuous information to become available to the decision makers and therefore for them to be in a position to organise all the stages of the response operation, the remote operational units of the emergency authorities of the area have to be deployed. Along with their rescue responsibilities, they have to contact regularly the operation centre in order to provide them with descriptions of the current situation. At the same time the teams receive new orders of action according to the progress of the operation.

The findings described in Chapter 4 indicate that communication methods used during the response phase consist of modern computing and telecommunication facilities. The information collected is stored and assessed in the computerised systems of the local emergency management unit. Based on this information the leaders of the authorities involved make decisions and give orders of action to the operational units, in order to be informed about their next steps and the resources available. At the same time, the remote operational units provide feedback to the operation centre, in order that the participants in the decision-making process come forward with new decisions about the actions required. Amongst others, the following ICT limitations have been identified:

- *Gathering of stakeholders to a centralised place is time consuming and*
- *Limits access to individuals' centralised resources/data;*
- *Non-timely exact information about the phenomenon;*
- *Not exact information about available resources;*
- *No real-time pictures;*
- *Possible computer network failure;*
- *Centralised store of important information;*
- *Incompatibility of the computerised means of communication.*

These limitations clearly suggest that there is a need for a computerised method that will allow emergency management decision makers to make more informed decisions via the incorporation of the minimum activities presented above in a dynamic fashion. That is to say, the ICT method adopted should fulfil the following set of requirements as seen in Table 5.1.

Table 5.1: The Set of Requirements for the Emergency Response Model

SET OF REQUIREMENTS for the EMERGENCY RESPONSE MODEL
1. Emergency management authorities' stakeholders to work remotely and collaboratively in order to plan, control, coordinate and communicate relevant actions in a more effective and efficient way;
2. Stakeholders to receive dynamically the most up-to-date information about the current situation (upon request);
3. Stakeholders to dynamically receive the most up-to-date information in relation to what resource is available to use (upon request);
4. Stakeholders to work in an environment that is free of any ICT compatibility problems
5. ICT resources to dynamically collect and store the most up-to-date information about the current situation;

6. ICT resources to dynamically assess and allocate incomplete jobs to other available resources if they become unavailable;
7. ICT resources to interoperate in a compatible way;
8. All resources to dynamically and collaboratively work in an environment as defined by the set of policies.

5.3.1.1 Description of the Proposed Conceptual ERM

Integration of all findings as discussed above led to the identification of the following statement that stands as the Emergency Response Model (ERM) that is the proposed conceptual model of how emergency response management could be more effective and efficient during situations caused by natural disasters:

- *A system owned, managed and operated by the emergency management and other directly involved authorities when a natural disaster occurs, to assist the collaborative nature of the emergency response and rescue operations, by improving the effectiveness and the efficiency in terms of controlling, coordinating and communicating the emergency management procedures and the relevant resources. In particular, the model suggests the collaborative and dynamic provision and use of all currently available resources and instrumentation in order to dynamically collect all data relevant to the situation concerned. In turn, data should be dynamically stored and collaboratively and collectively assessed and, if required, to dynamically alert relevant resources including stakeholders about the situation concerned. Individual and/or collaborative resources as decision makers should be able to collectively access as much as possible from relevant and accurate collected dynamic data in order to collaboratively and collectively assess data and make an informed decision that should be dynamically forwarded and allocated to an appropriate and available collaborative operational unit(s) and/or other collaborative resource(s) as specified in the job plan. Following this, the operational unit(s) and/or other resource(s) have to take collaborative action(s) and run the allocated job(s) and finally, to dynamically report job(s)' completion, failure or the need for additional* *resource(s). In the event of the need for external resource(s), the system should dynamically alert relevant decision maker(s) to allow external resource(s) to collaboratively join. Finally, for all these functions to run smoothly and according to the bodies of law, the codes of practice, the quality of service, the ethicality and other issues including environmental and humanitarian concerns, a set of pre-defined and/or dynamically generated policies as required appropriately should be embedded.*

SSM epistemology also suggests the need for monitoring and measuring the performance of the model so relevant corrective actions can be employed. The exact identification of relevant criteria to measure the model's performance will be discussed in detail in Chapter 8.

The proposed ERM is illustrated in Figure 5.2 and depicts the organisation and interrelationships between the minimum activities required to complete the transformation (T) as described earlier. The graphical representation method that is used to illustrate the conceptual model as a whole is derived from current SSM epistemology as has been suggested by Checkland and Scholes (1999). They state that 'the stages can be carried out on a computer screen, or in hand-drawn. They need to be in egg or cloud shapes, rather than rectangular boxes. The reason is psychological; it acknowledges the model's role as pragmatic devices, not definitive once-and-for-all statements'. Further statements and examples of the SSM application and representation methods can be seen in Chapter 2 of this thesis, where the literature review of SSM is presented. The gray egg-shaped area illustrates the space of the model. The smaller white egg-shaped areas illustrate the different activities the model accommodates and the space of its individual activity. The arrows demonstrate the order of actions and the interconnection between activities. Further to this, the small non strait line arrows demonstrate the ability of the model to receive and/or forward information outside its borders. The ERM is able to interact with relevant instrumentation, governmental bodies – that are able to amend policies – and external experts, such as structural engineers, whose expert advice is considered important in cases like the occurrences of strong earthquakes in urban areas.

Overall, it is believed that the proposed conceptual ERM will facilitate emergency management stakeholders with an up-to-date picture of what is available and what is known so that emergency management decision makers increase their possibilities in identifying a better solution in order to control the situation.

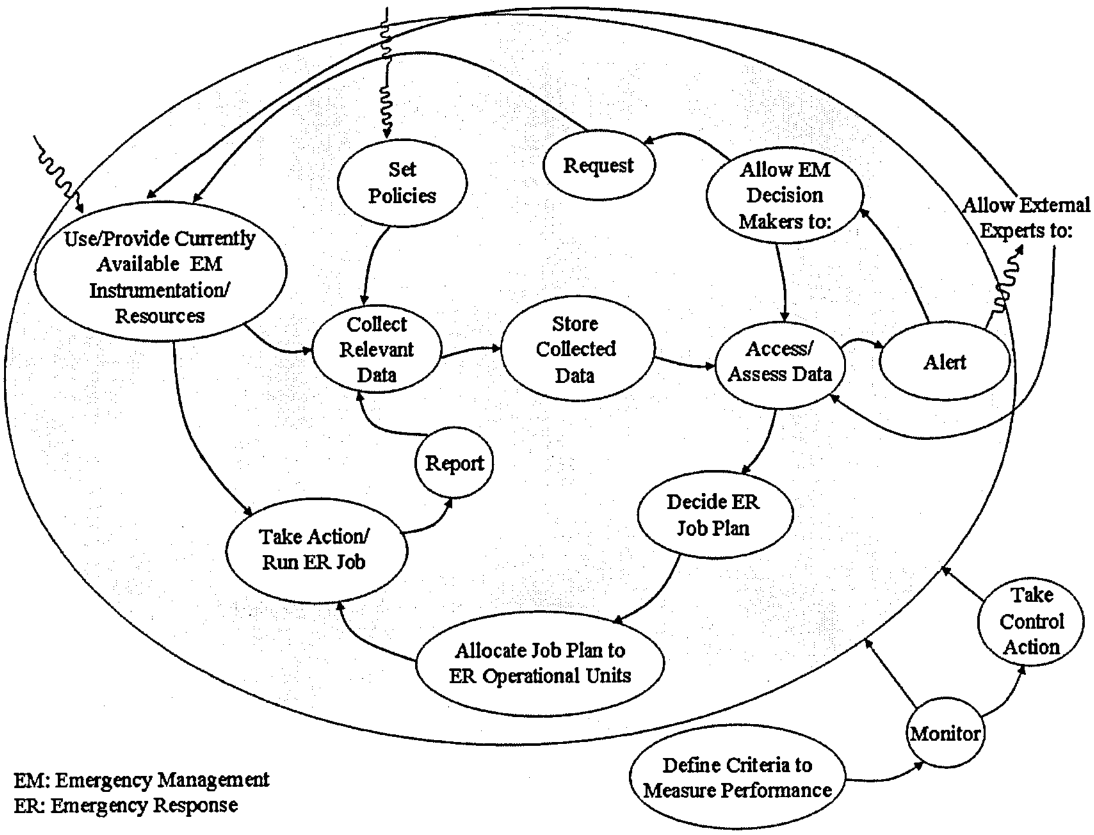


Figure 5.2: The Proposed SSM-Based Conceptual Emergency Response Model (ERM)

5.3.2 Detailed Description of the ERM

This section describes the proposed conceptual ERM. Section 5.3.3, based on primary and/or secondary research findings, provides a deeper understanding of the activities and the relationships between them.

The main activities of the proposed ERM include the use of the currently available emergency management (EM) instruments/resources – internal and external – from which the ERM should collect the relevant data. This data consists of information about the natural phenomenon that has occurred in terms of its main characteristics, such as its nature, magnitude, time and area of occurrence and every other scientific information related to the phenomenon. The data also includes the disruption, which the occurrence of the event has caused so far, the available resources of each authority involved, along with their characteristics, such as expertise and quantity, as well as any relevant forecasts available. The ERM should store this information and then, with the expert contribution of the decision makers of the authorities involved, who need to have already been alerted by the ERM to access and assess this collected data, in order to decide on a specific job plan according to the level of the emergency. Based on the decided emergency response (ER) plan of action, the ERM may allocate the ER job plans and forward them to the relevant ER operational units. These units may be human- or computer-based, according to the nature of the job needed to be done. After the allocation of the job, the units take the relevant actions described by the ER job plan and they should report back to the ERM the outcome of their process. All the processes need to be agreed well in advance, between the parties involved and therefore a set of policies should always be running during the operation to make sure that the processes are kept in line with the agreements, such as the bodies of law, private agreements between companies involved, codes of practice, ethics and other important operational factors.

In order for a more detailed description of the proposed conceptual model to be derived and the SSM processes to be applied, a case scenario has been produced and this is presented next.

5.3.3 Case Scenario

The previous section has described the holistic function of the proposed ERM conceptual model. The following sub-sections are concerned with the functions of specific parts of the ERM, as it should be able to operate as a whole, as well as in parts.

The case scenario describes an emergency situation caused by a sudden earthquake in a city. Based on the case scenario, the different functions of the proposed ERM are demonstrated through the viewpoint of the different parties involved, including the ER Operational Unit; the EM Decision Makers; the ICT Infrastructure; the External Computing Power; the Expert Request; and the Alert/Error. This method attempts to describe human-related jobs, as well as mechanical tasks.

5.3.3.1 Emergency Response (ER) Operational Unit View

For the purposes of the case scenario, one operational unit (OU) has been taken as an example. This is the OU of the Fire and Rescue Service. The main activities of the OU of the Fire and Rescue Departments (FRD) include fighting small fires (houses), bigger fires (neighbourhoods, public buildings), forest fires, general public rescue (lift rescue), as well as the preparation of the relevant equipment they use during action. One of the most demanding roles that an OU has – infrequent, but it is considered as very important – is to take part in emergency response operations of large scale events occurring in the area of their responsibility. In these cases, they have to work as a team, along with colleagues and with members of other internal and/or external bodies taking part in the operation under the orders of their leaders. As the OU's expertise is fire fighting and rescue, they work on-site, under the coordination of the team leader of the unit. Figure 5.3 illustrates the organisation of a Fire and Rescue Department.

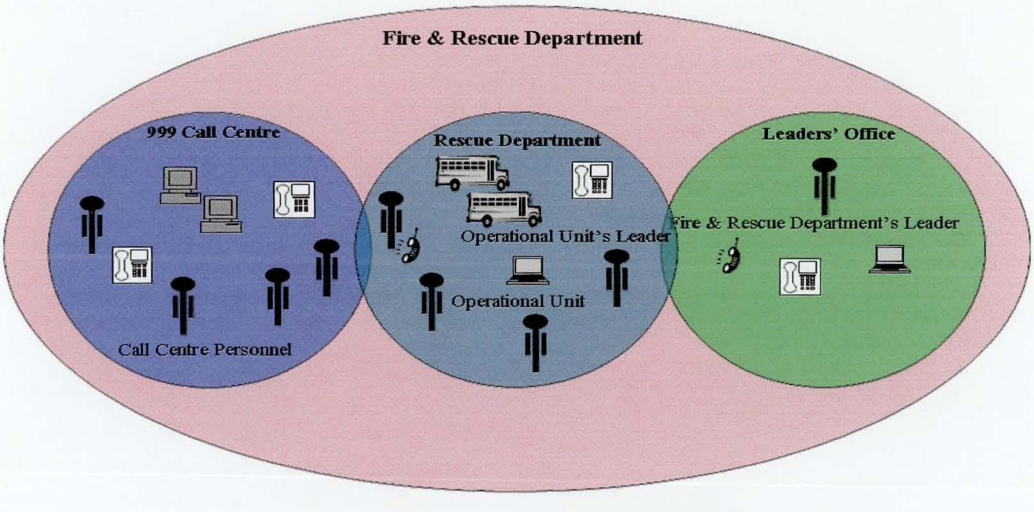


Figure 5.3: The Fire and Rescue Department

When a large-scale earthquake hit a city under the responsibility of the above OU, people working in emergency management authorities physically felt the phenomenon. However, there was no visible damage to the buildings accommodating them. Minutes after the event a 999 call reached the call centre of the Fire and Rescue Department. People calling from mobile phones were reporting that they were trapped underneath a collapsed building after the occurrence of "something". Note that the occurrence of "something" refers to an event that is undefined, unknown and unexpected. Call centre personnel needed to find out more information and first of all, where exactly the collapsed building was located. Trapped people were frightened and stressed and therefore, they were not able to communicate normally. However, they revealed the address of the building and that it was a four-storey office block.

The call centre staff should have the ability to log into the ERM and to search in the database for the address of the collapsed building. Through the official map provided by the city council's planning office they may find out the exact information about the use, scale, location and access of the reported building. In addition to this, they should find out information about the wider area, such as the surrounding buildings and their use. Instantly they should send an alert message to the leader of the OU through their communication ERM, informing him about the current known situation, the collapse, the building details and the number of people reported as victims so far. Call centre operators should then store all relevant information in the database.

In the meantime the relevant part of the ERM should have already started to automatically collect data about the occurrence of the phenomenon through the assigned instrumentation of the relevant bodies, such as the geological instruments of the geological organisation and the weather station of the area. The collected information should be stored in the storage part of the ERM. The next step should be the assessment by the ERM of the collected information, which revealed that a large scale earthquake had occurred. The assessment stage should have been related to the collection of all the relevant information provided by internal and external instrumentation to the ERM and according to predefined parameters, the type of the phenomenon and the potential damage it has caused to the area of the occurrence. After the first assessment process the ERM should put on alert the emergency management authorities, the relevant departments and the EM decision makers. All these functions of the ERM must be predefined and secured in advance through the set of policies as described in Chapter 4.

The ERM should continuously collect data by the registered instruments, store this data and forward it to the EM decision makers in order to run the assessment process. Meanwhile, the call centre was receiving continuous calls from people asking for help. Call centre staff doing the same actions as described above, found out that there were more collapsed buildings and more people trapped in different areas. Clearly, the ERM should not allow storing of information about buildings already reported as these are under assessment else these are redundant information. However, they should have been able to store information related to the names and number of people calling from the buildings already reported, as well as the location they were in before the collapse (floor number, toilets, etc.). That is to say, new information about calls related to new incidents about different areas will be stored and will be made available for assessment.

Meanwhile, the OU of the Fire and Rescue Department should have arrived at the area of the collapsed building mentioned earlier. Figure 5.4 illustrates the movement of the operational units of the fire and rescue department during the emergency. The leader of the OU needs to be able to retrieve the information, which has been made available to him via the ERM. Information may include but not be limited to ER job plans, in order for him to organise his/her team and respond to the situation appropriately. This process should take place through the use of a portable computerised device, or any other relevant equipment. The OU leader should be able to access relevant information that is stored in the ERM via an authentication method (i.e. log in). To achieve this, the OU leader needs to log in to the ERM in order to receive and view the ER job plan that has been allocated to his/her unit after the assessment made by relevant decision makers.

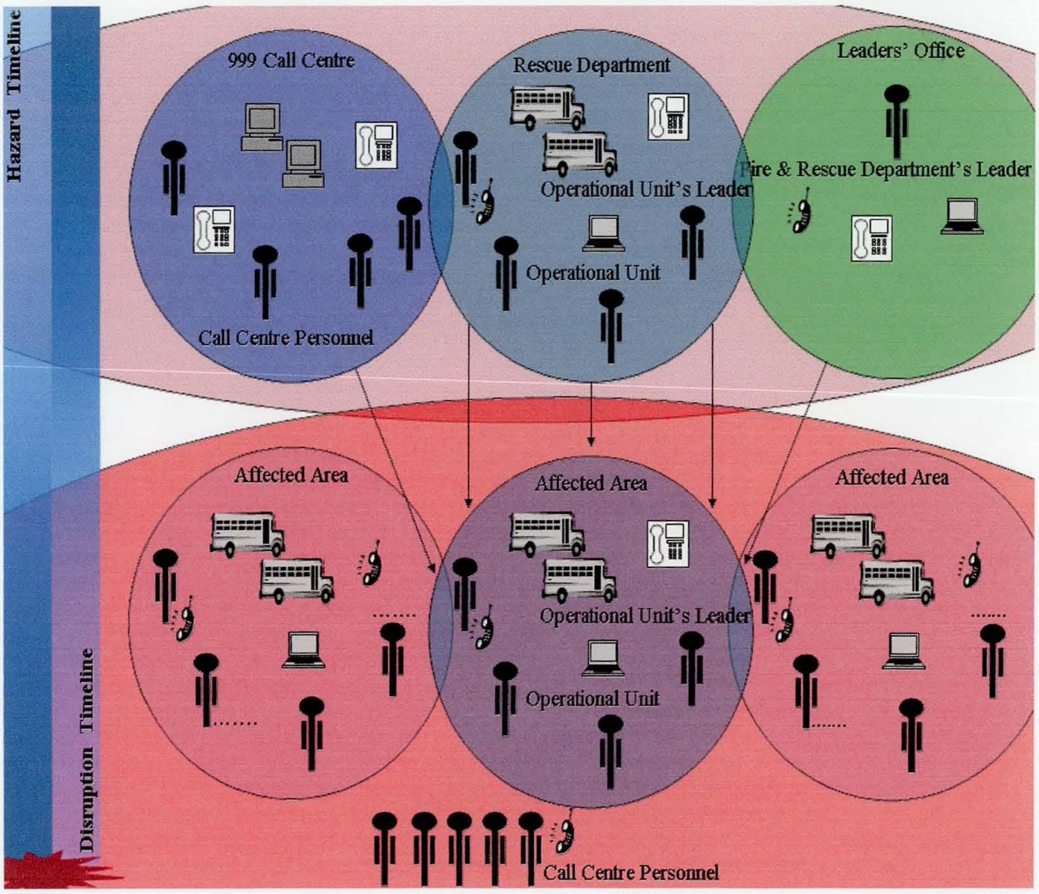


Figure 5.4: Example of ER Operational Unit in Action

Once the OU has completed the assigned job plan, the leader of the unit should report to the ERM that the team had completed the allocated job successfully. The ERM's update should run immediately and then the ERM should allocate this particular OU, along with their tools and equipment as available resources. This function should be used in order to enable the ERM to pass the service availability through the assessment process again in order to allocate them with another job. When the next job plan for this OU has been decided, the ERM should allocate it and forward it to the OU leader. The leader may receive it by laptop, PDA or any other voice-enabled communication equipment, such as VHF radio and/or mobile phone, which should transmit the voice message describing the job plan. The OU leader needs to gather the team again using the team's communication equipment, in order to start the next mission assigned to them. The same processes and ways of communication should be used for the rest of the operational units taking part in the emergency response operation. Figure 5.5 is the graphical representation of the part of the proposed conceptual model, which should support the communication and the processes of the operational units during the emergency response operation.

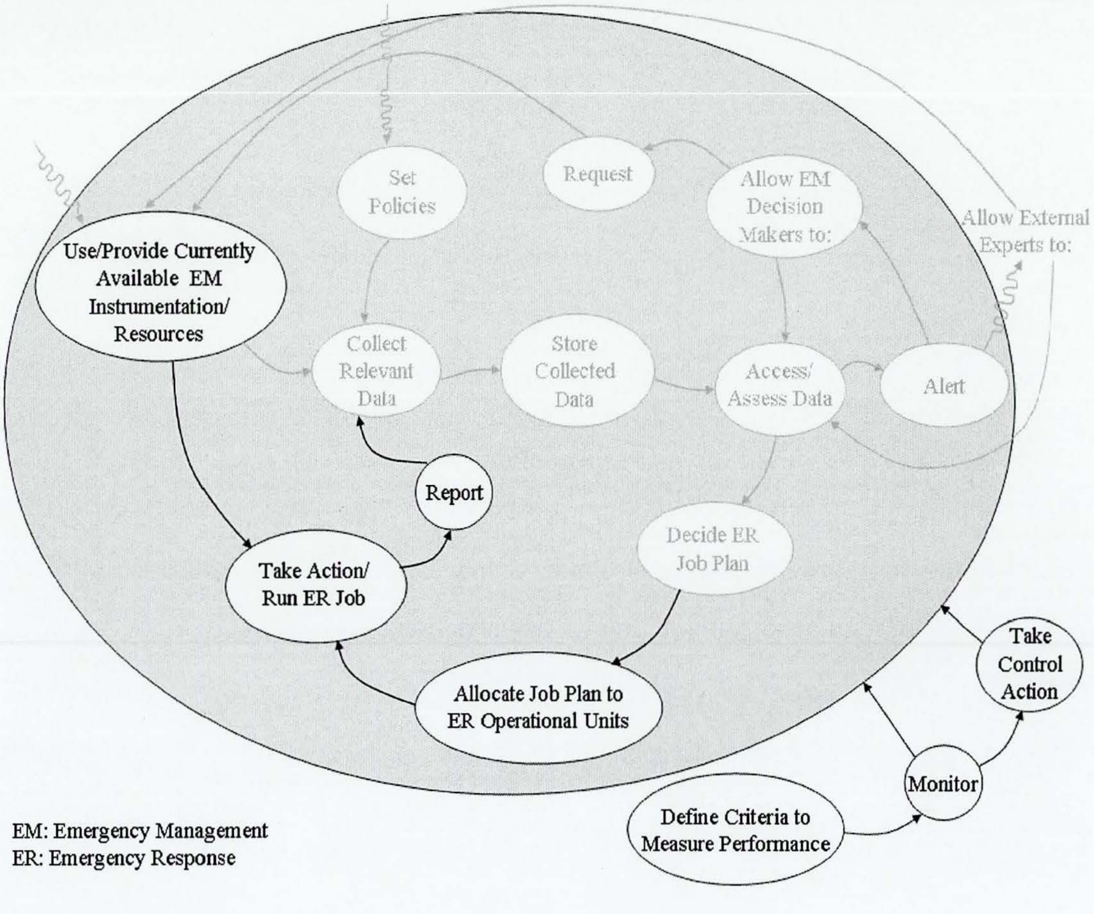


Figure 5.5: ER Operational Unit View

5.3.3.2 Making Decisions View – A Human-related Task

The OU mentioned in Section 5.3.3.1 belongs to the Fire and Rescue Department of a particular city. According to the hierarchical organisation of the body, above the leader of the OU there is the leader of the whole Fire and Rescue Department. The role of the Fire and Rescue Department leader during an emergency situation caused by a natural disaster is to take part in the decision making process, along with the leaders of the other authorities involved in the emergency response operation.

According to the proposed conceptual model, the Fire and Rescue Department leader should have been informed about the emergency situation by the ERM's alert function. When the ERM collects and assesses the first data it should alert the relevant decision makers of the potential for an emergency. When the situation is established as an emergency in need of response the ERM should alert the relevant authorities' leaders that they need to have a virtual meeting to coordinate the emergency response operation and their resources.

The conceptual model proposes that, during the virtual meeting between the authorities' leaders, the model should be able to authenticate them via the log-in facility into their part of the ERM in order to have access to the relevant stored data and the ability of communication between them. The ERM should collect and store all the information provided from the different instrumentation assigned to the ERM, the call centre, as well as the comments from the OU team leader, who is working in the area of the emergency. The decision makers should be able to assess the situation in terms of needs and in terms of the availability of the resources of each authority. According to the level of the emergency and in the cases that the situation exceeds the capabilities of the local authorities, their leaders – as decision makers – should be able to inform the leaders of their authorities at county level about the situation, via the proposed ERM.

Through the part of the ERM available to each leader of the local authorities involved to the emergency response operation, they should be able to see in real time what and how their resources are working in the operation through the images and the reports they receive. Additionally, they should be able to see what is required in the area. Figure 5.6 demonstrates the hierarchy of the departments of the authorities involved in emergency response operations, using as samples the Fire and Rescue and the Police Departments.

During the emergency response operation, the county level leaders of the authorities involved should have access to their part of the ERM and be fully informed about the current status of the operation, the exact location and status of their resources. They should be located in their offices, where they have access to other important information stored in the ERM about specific subjects, such as maps, legislation, availability of the resources from other municipalities in the county, etc., or in any other place according to the current needs.

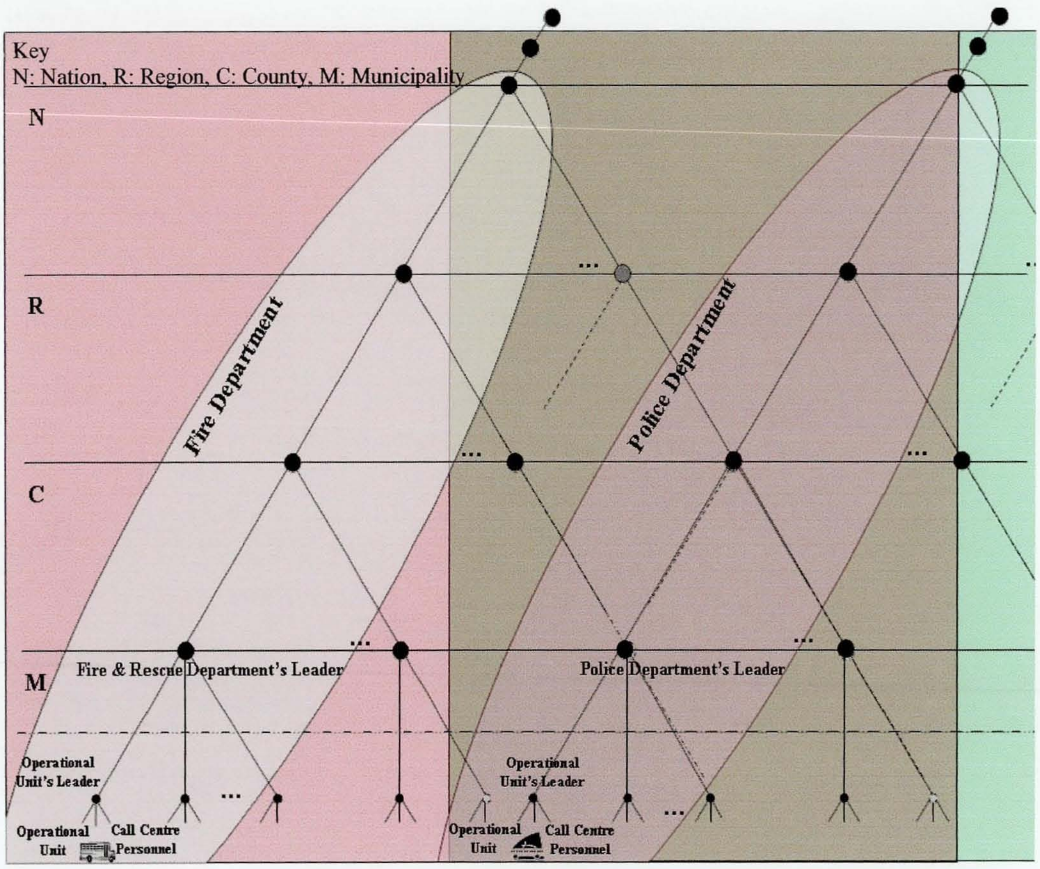


Figure 5.6: Hierarchy of Authorities Involved in the Emergency Response Management

According to the emergency management stakeholders that took part in the interview exercise of this research, the main role of the county level leaders relates to the arrangements for support from the neighbouring municipalities and neighbouring counties. These processes should take place via the proposed ERM, as it is suggested by the study that each municipality, county and region of a country should be equipped with the ERM so that the whole of the county – at all hierarchical levels – can be interconnected during the management of emergency response operations to natural disasters.

Figure 5.7 demonstrates the part of the ERM related to the collection and assessment of relevant data and the decisions on the ER job plans, which the authorities' leaders participate in.

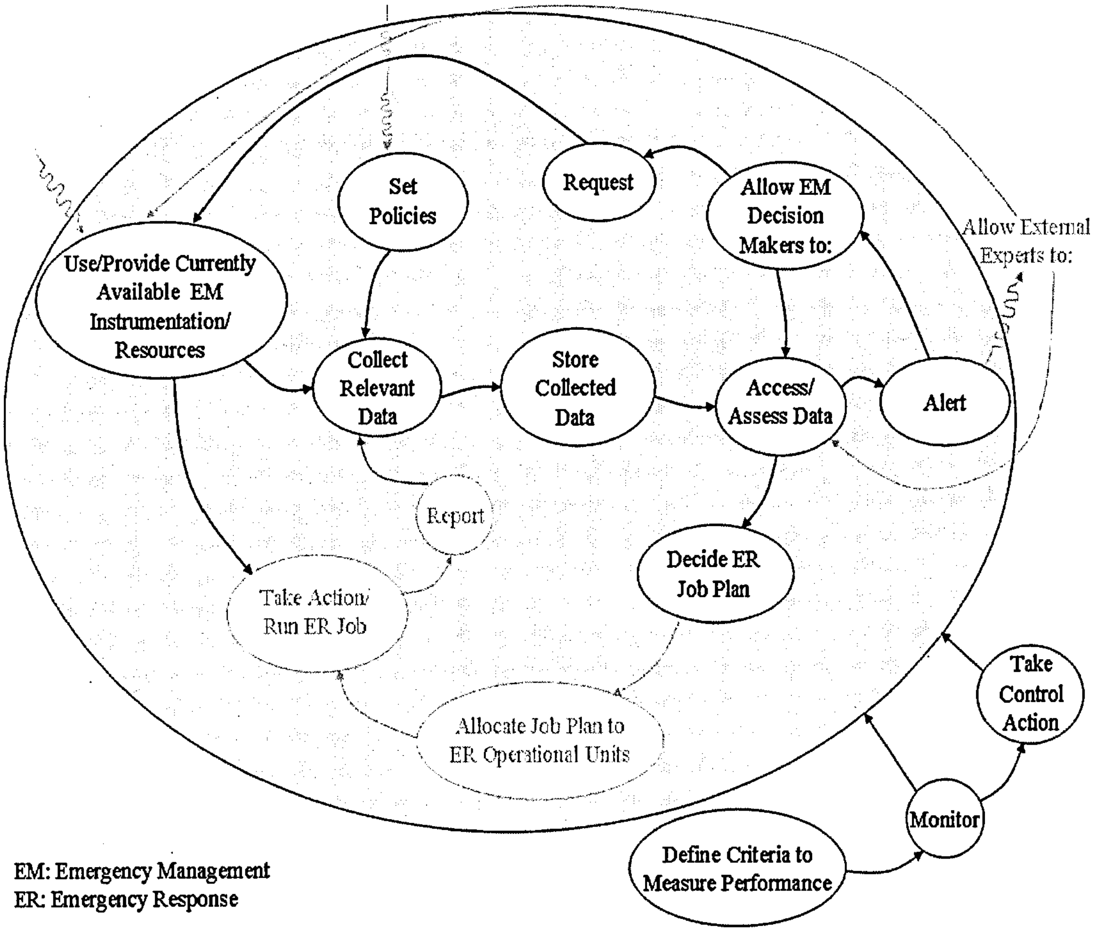


Figure 5.7: Making Decisions View

5.3.3.3 ICT Infrastructure View

It is also considered important to explore another function of this part of the proposed ERM. The operational units may consist of humans and/or a sum of instrumentation resources, such as computers, which are needed to run a specific job. For example, when there is a badly affected large-scale building, which contains a large number of people, the rescue teams need to know the available safe time limit they have in order to evacuate it, before its potential collapse. In this situation, the ERM should collect and provide access to relevant stored information in order to assess it and alert the external experts of the situation.

These items of information about the buildings may be stored in the form of files in relevant engineers' computerised ERMs and/or in the planning department of the city. Relevant information may include, but not be limited to, data related to the building, such as drawings, materials' specifications, evacuation routes and any other essential information defined by the external experts. The job plan decided should be made available in the form of an allocated job to the infrastructure, which has to act as the operational unit.

The job plan is about the calculation of the time frame the rescue teams have in their availability to safely evacuate the building. The networked computers should have to run all together to complete the requested calculations and to report back to the ERM the results. These results may be related to the final output, or to any other demand there is in order for them to run the job, or potential errors that have been occurred. The hardware utilised to create the infrastructure should be the existing hardware of the emergency management authorities and the bodies involved in such situations, which through the set of policies should be able to communicate and interoperate their data and to share their computer power.

The internal computers should be responsible for running the ERM, as well as searching the stored information in the databases of each department, to allow access to the relevant people in the part of the ERM of their interest. Apart for these functions, the infrastructure should allow use of these computers on demand in terms of Central Processing Unit (CPU) power jobs, such as heavy calculations, audio visuals of the area of the disruption and 2D/3D representation and simulations of the affected area or buildings.

Figure 5.8 demonstrates the functions, which should be carried out by the internal computation capabilities of the ERM.

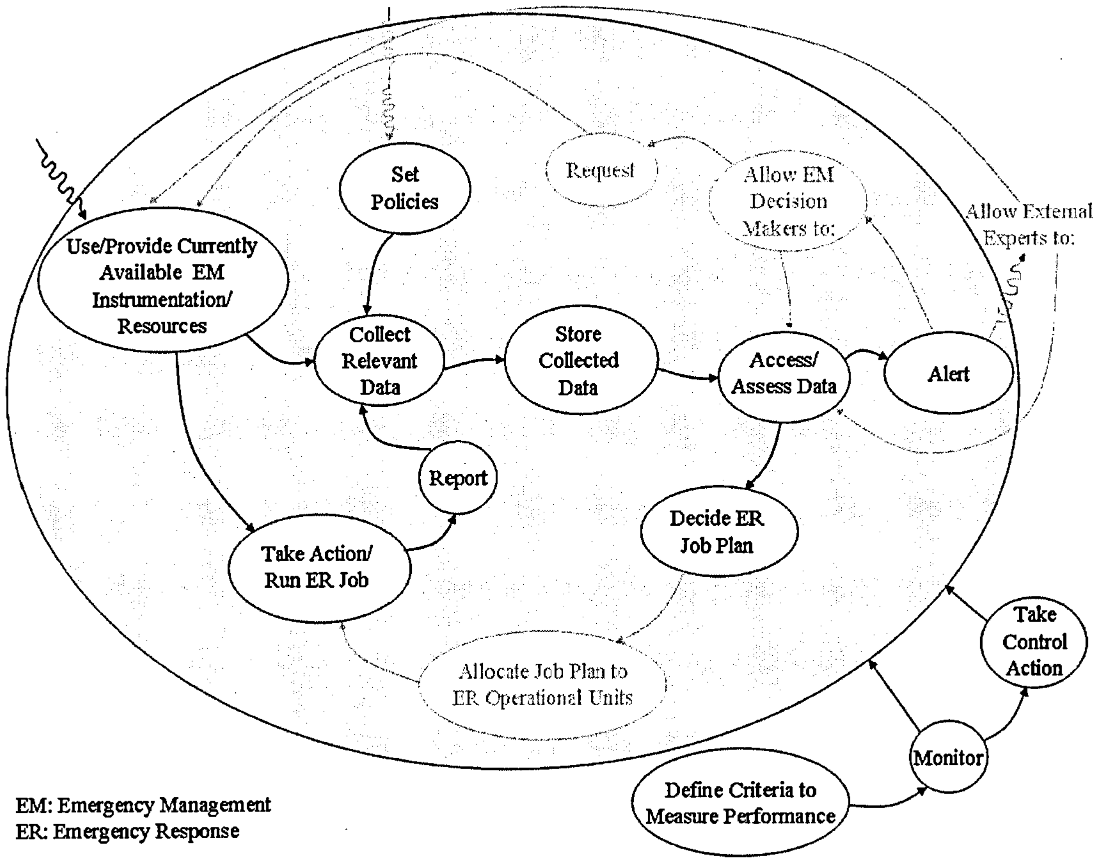


Figure 5.8: ICT Infrastructure View

5.3.3.4 External Computing Power View

There may be situations in which internal computing power may not be considered enough to complete a task on time. In such cases, the ERM should be able to identify relevant external resources, which may assist in completing this task on time with minimal risk. These external resources may consist of any idle machines in the area, such as computers available from banks, schools, or business equipment, which through the set of policies become available for this purpose.

Returning to the earthquake scenario, it has been stated that the earthquake has affected a four-storey office block that is full of people. The on-site relief units found out that it was so badly affected, that it was too risky for them to go inside and evacuate it. Therefore, the leader of the OU should request advice from his department through their communication tools. The leaders of the authorities at county level decided to run a simulation to find out more about the damage to the specific building, its weak areas, the shorter and safer evacuation routes and the lead time for its potential collapse. This is the ER job plan, which should be allocated to the computers of the ERM, which in this situation act as operational units.

The ERM should be required to run a number of enquires in order to find all the relevant data, including technical drawings and details, such as structural calculations, materials' specifications and any other building-related information. This process may involve the cooperation of external computers (as data stores) of the required information, which through the set of policies should have been allowed and ordered to participate in this process. Further to this, it may be the case that when this information is collected the ERM discovers that the CPU power is not enough to run the requested calculations and simulations within the time ordered. Then, through the assessment process, it should be able to calculate the number and specifications of the extra machines required and to alert the decision makers about this demand.

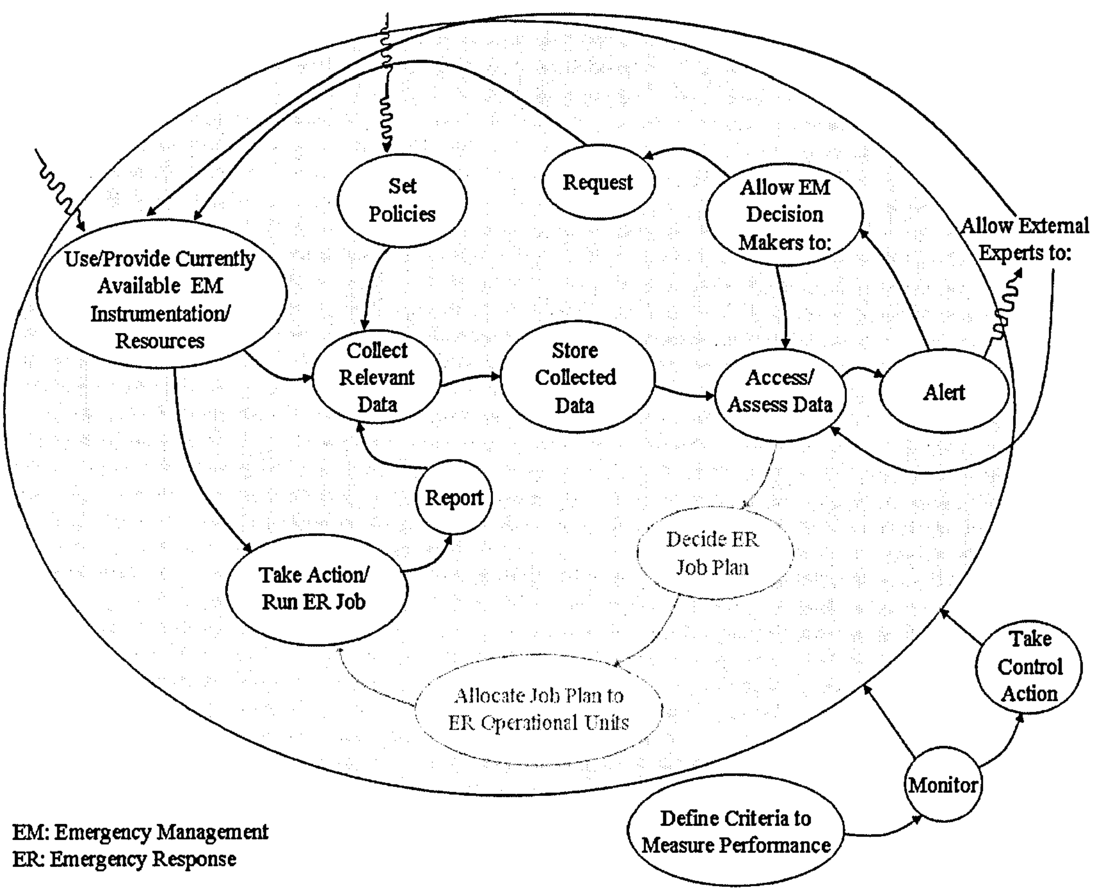


Figure 5.9: External Computational Power View

At this stage the decision makers may request these resources from available decision makers in the neighbouring areas. Once external decision makers agree to allocate their resources the ERM should forward the ER job plan to the external machines, which they need to work together with the internal ones in order to run the allocated job. Together they have to report their status during the process and their sub-results and/or end results on the completion of a job to be pushed to the responsible parties at the next stage. Figure 5.9 illustrates this process.

5.3.3.5 Expert Request View

As mentioned in Section 5.3.3.3, there is sometimes the need for external experts, depending on the level of disruption and the individual characteristics of each emergency situation. These could be engineers, geologists, meteorologists, politicians or any other relevant professional. The ERM should have the ability to alert these people if the "access/assess data" (model's activity) reveals that there is the need for their expertise.

The identification of specific external individuals or bodies has been established in advance. Internal and external resources should have specified their willingness to collaborate through the set of policies, which act as the constraints on who is doing what, for what purpose and under what conditions. Access and permission rights should have also been described in the "set of policies".

Hence, if there is a requirement, the ERM should inform the external experts of the time they are required to join the decision making process and assist it as required. Their expertise may be used to support the decision makers to make, as much as possible, more informed decisions about the progress of an operation. Figure 5.10 represents the external experts' alert and involvement in the ERM.

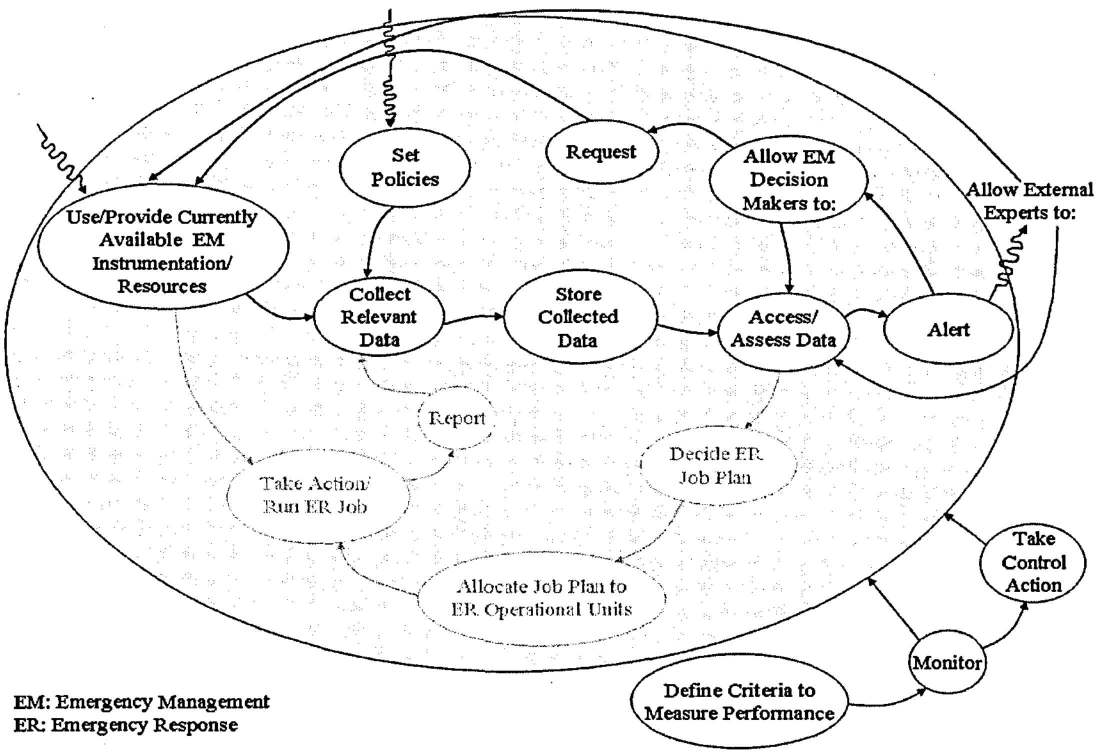


Figure 5.10: Expert Request View

5.3.3.6 Alert/Error View

When there is an error or conflict during a function or a series of functions the ERM should have the ability to alert the relevant cooperating/collaborating resources and functions about the problem. Problems may be caused by the failure of a part of the ERM, an instrument, human error, incomplete job plan, incomplete job execution, report failure, job/action failure, requirement for more resources, or by any other external cause, such as electricity shut down or network overload.

Every time that the ERM starts up, it has to check if all of its components are in working order. However, in the situations described above, the ERM should be required to run an additional check in order to identify and locate the conflict. If everything is correct, it should return and evaluate the collected data and loop the process. If the problem is not solved the alert function should signal to the decision makers, who are responsible for re-running the assessment process and changing some of the parameters they previously fed into the ERM. In the case of a technical problem or when the change of parameters does not solve the problem, the ERM should contact its analogous one in the neighbouring area and assign to it the part or the whole of the process, giving access to or forwarding parts or all data already stored. Figure 5.11 illustrates the function of the ERM when there is an error.

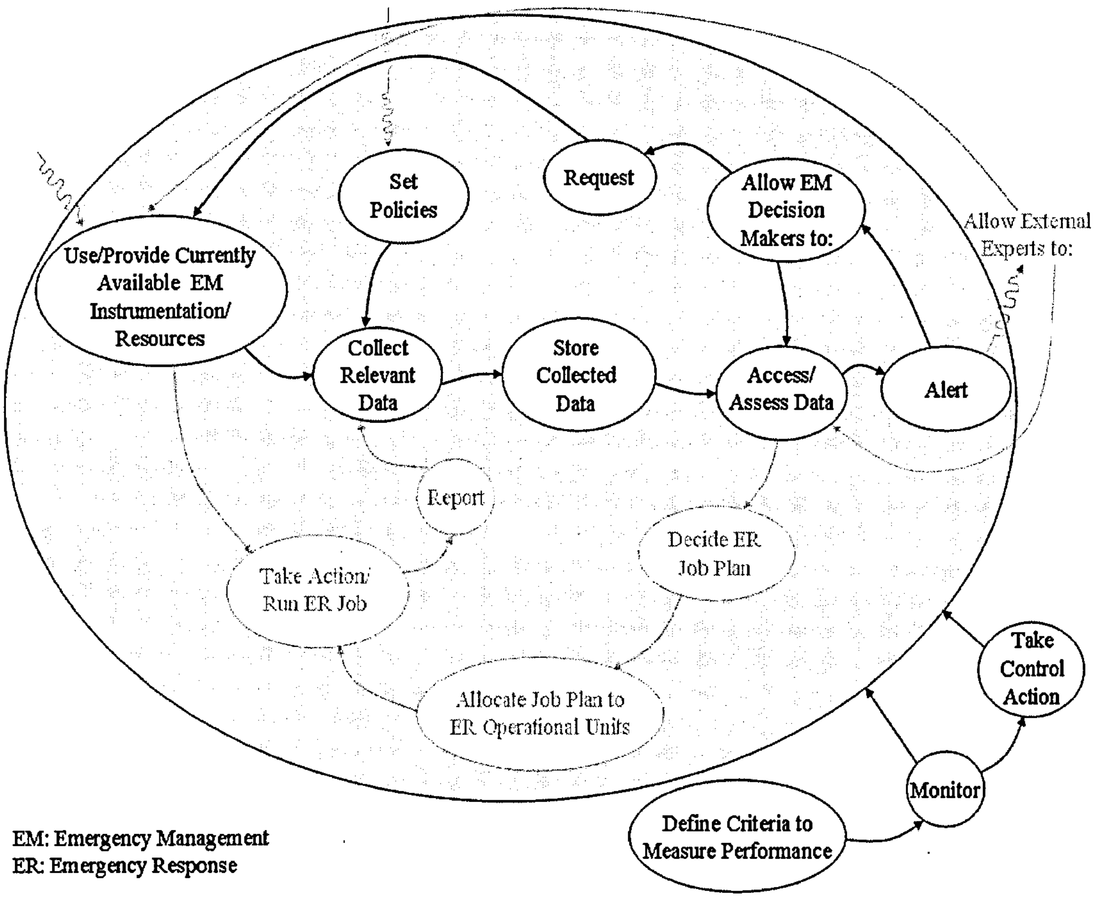


Figure 5.11: Error View

5.3.4 Key Activities of the ERM

The following sub-sections are concerned with the detailed description of each activity (seen in the form of a bubble in the figures) so that some of their components can be identified. This will further demonstrate their role and their potential contribution to the completion of the overall conceptual model's activity. This also exemplifies how the current provision should be used, but it should not be treated as an exhaustive exercise, as the author has not access to and the full knowledge of all the components being used by the authorities involved, as some information is confidential and could not been given out. For example, the purpose of the study is not to present the exact part of the body of law, which covers the emergency response operations, but to appreciate that this process exists. Each activity consists of, but is not limited to, components which have been identified through the literature review on the selected case studies and the interview exercises conducted with the emergency management stakeholders, which have been presented in Chapter 4. However, these do not exist as an entity in a particular form of a model. Their inclusion in the model and graphical representation has been created in line with SSM representation methods and according to the activities of the proposed conceptual model.

5.3.4.1 Set Policies

The "Set Policies" is considered to be one of the most important parts of the ERM. This is because it refers to a series of predefined regulations, agreements and issues, which should be used to support the smooth running of the ERM itself, as well as the whole emergency response operation.

This part of the ERM should be responsible for keeping all relevant and up-to-date information about the distributed resources. These may include information about external expertise, decision makers' responsibilities, instrument constraints and ultimately, information on who is doing what, for what purpose and under what conditions. These may also include: the bodies of relevant law; the aim of emergency management; good practice and quality of service issues; the security, cultural, religious, economical and ecological issues; and anything else defined in advance by the relevant authorities. The information stored in different places needs to be collected by the ERM and the particular parts of each issue should be retrieved and sent in the data collection part to guide and secure the decision process. Once this has been done, the "Store Collected Data" activity should be able to store them via the "Collect Relevant Data" activity. Then, the decision makers should be able to run specific enquires to access them alongside other stored data describing the situation in order to "Access/Assess Data". The assessment process should assist them to propose and issue a job plan based on who needs to do what, for what purpose and under what conditions as a response mechanism. In addition to this, the correct combination of relevant issues needs to take place according to the nature of process, job or personnel. Note that the ERM should be available to all the hierarchical levels of the country. Hence, it should have the ability to request an unarranged specific agreement from the relevant governmental body, if it is required during the response process. Figure 5.12 illustrates the components of "Set Policies".

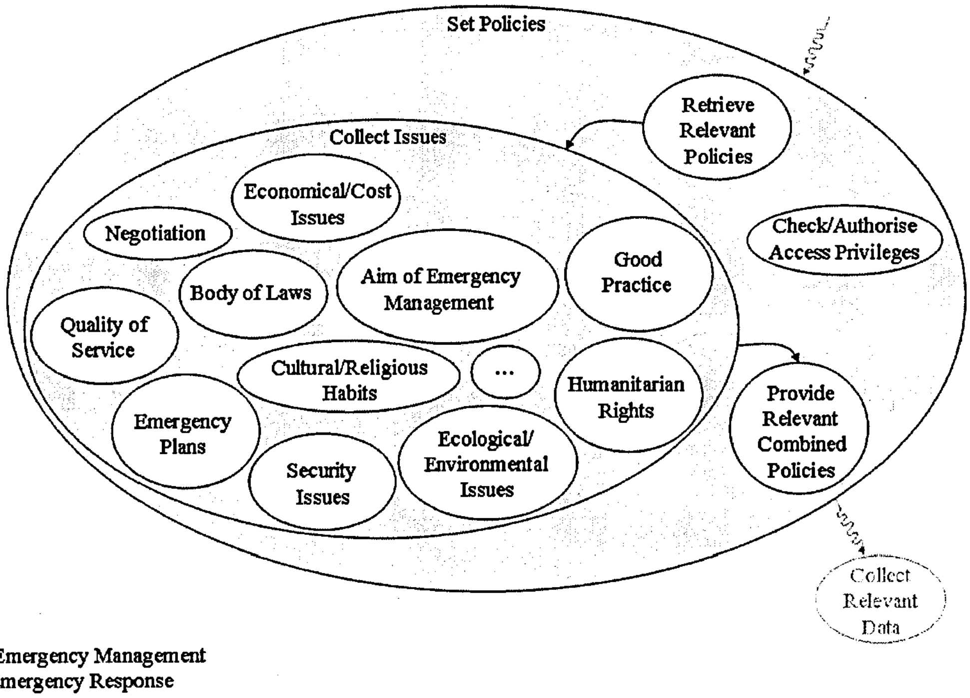


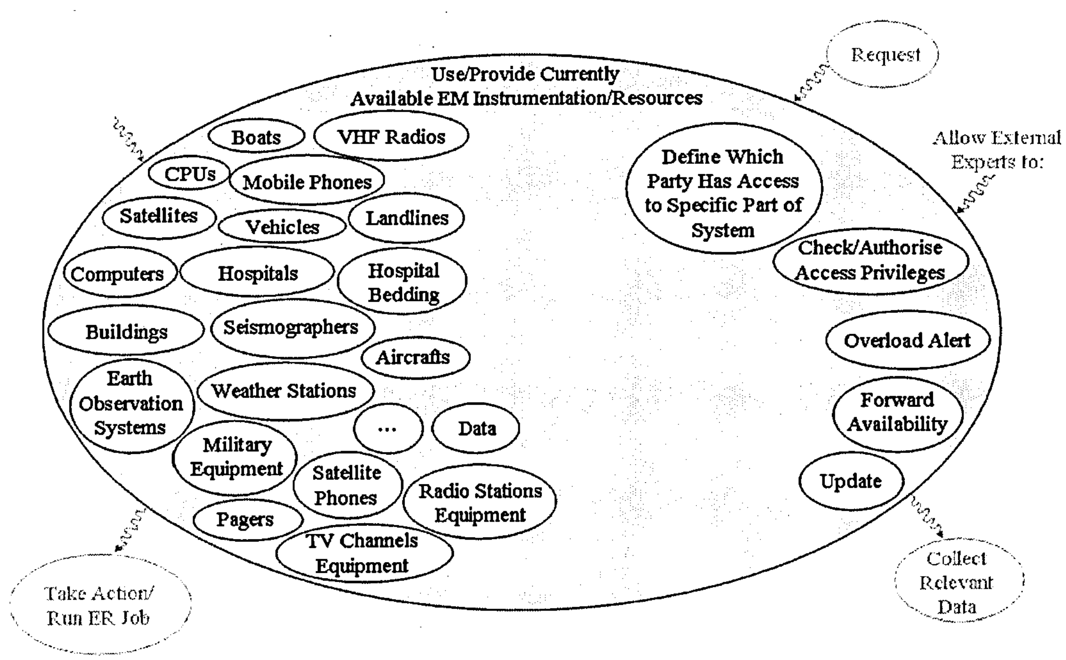
Figure 5.12: Set Policies

5.3.4.2 Use/Provide Currently Available Emergency Management (EM) Instrumentation/Resources

This activity should be responsible for identifying and allowing access to all the instrumentation and human resources registered with the ERM at the time of the occurrence of a natural disaster.

The first involvement of this part of the model may take place instantly, with instruments (such as seismographs, weather stations, satellites and computers) or relevant scientists informing the model's activities that a natural phenomenon has occurred in the area covered by the particular ERM. The ERM should collect the information and feed the next activity with the relevant data. Along with the area characteristics, the ERM may collect relevant data and following the set of policies, has to store them and provide access to relevant instrumentation to assess the potential disruption that may be caused by the specific phenomenon. If the magnitude of the phenomenon is not enough to cause disruption, this part of the ERM should remain active along with all the other instruments until the phenomenon is fully passed. If the phenomenon is considered as catastrophic after the process of the "Access/Assess Data" activity the ERM needs to alert the relevant instrumentation and/or the decision makers, following their hierarchy, through the instrumentation available, indicating the level of emergency.

When the occurrence of a phenomenon has catastrophic results and a response operation needs to take place, this particular part of the ERM should be able to hold the available resources along with their identifications, characteristics, location and status, which need to be assessed along with the situation of the disaster in order for the job to be planned and allocated. The key components of this activity may include resources available for the authorities, such as weather stations, mobile phones, software, vehicles, etc.



EM: Emergency Management
ER: Emergency Response

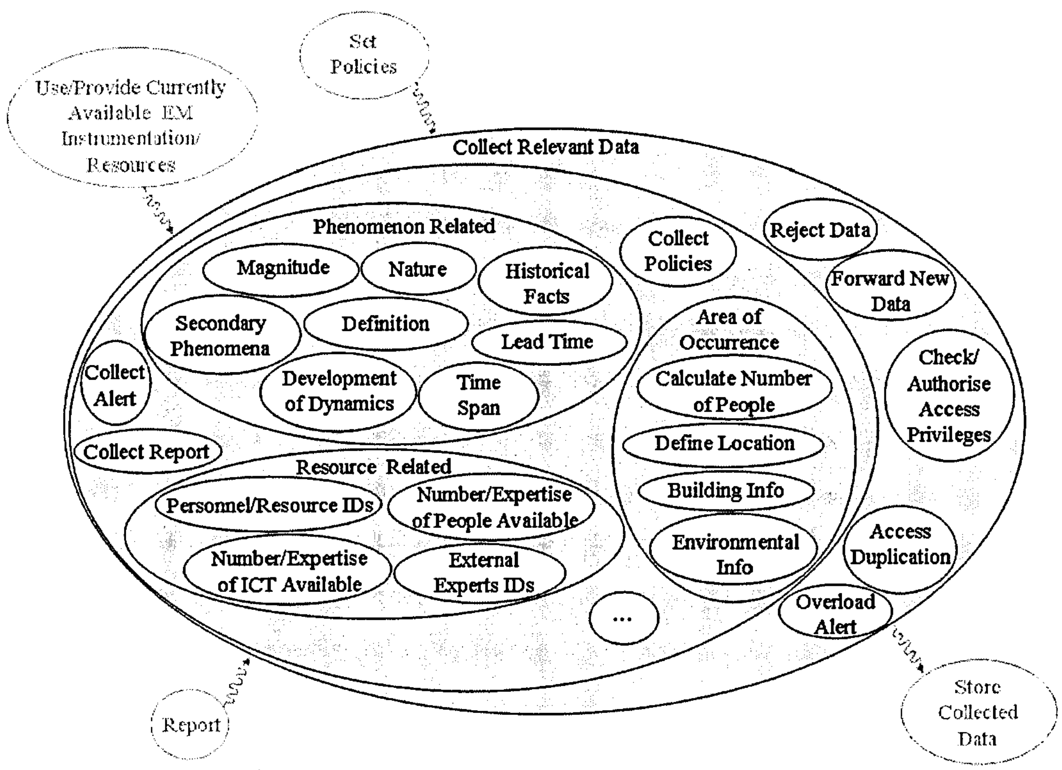
Figure 5.13: Use/Provide Currently Available EM Instrumentation/Resources

Figure 5.13 illustrates their inclusion, representing the resources currently used by the authorities involved in emergency response operations, according to the emergency management stakeholders form Greece and England. However, this should not be considered as a strict collection of resources, as the technological advances and/or individual laws, needs and arrangements of each country may cause a different sum of resources. In addition to these, the proposed model, along with its components is a concept and as such it should allow enough flexibility to accommodate different sets of components or even newer developments. It is also important to note that as in every other part of the ERM, this one should have the ability to give and check access rights and authorisation to relevant parties and it should be equipped with an overload alert for its own operational protection.

5.3.4.3 Collect Relevant Data

The "Collect Relevant Data" activity part of the ERM is the first and most important step before the assessment takes place. It is worth noting that the components of this activity have been identified during the interview exercise with the emergency management stakeholders of Greece and England and they have been incorporated into the proposed conceptual model. The ERM should collect the data, which is forwarded by the registered instrumentation and by the operational units through their communication tools. Figure 5.14 illustrates the "Collect Relevant Data" activity of the ERM.

This data should be divided into three main categories, the natural phenomenon related data, the resource related data and the data related to the affected area. The information about the natural phenomenon include information about its parameters, such as its magnitude, nature, definition, time span, lead time, development of dynamics, related historical facts and anything else that the scientists consider as essential for the assessment of a natural event. The resource related data contains information about the resource name, identifier, use, expertise, number of units, current status and others.



EM: Emergency Management
ER: Emergency Response

Figure 5.14: Collect Relevant Data

Finally, the data related to the area of the occurrence is about the number of people located in the area during the occurrence the geological, geographical and climatic characteristics of the specific area, the building and environmental information. The proposed conceptual model should also provide the ability for the emergency management stakeholders to add other categories of data as required.

5.3.4.4 Store Collected Data

The "Store Collected Data" activity as part of the ERM is the one following the data collection process. There should be a data pool consisting of different storage sub-pools needed for storage of the collected data according to some categorisation. This may include the storage of data related to the natural phenomenon, the available instrumentation, the reports, the policies, the external experts and any other type of information the authorities involved consider of interest. Overall, this should be considered as a collection of data related sources, including databases, files and other sources.

This part of the ERM should have the ability to store data based on its relevance as identified from the previous ERM activity, in order for this to be stored and provide access to the decision makers to allow them to carry out the next activity. This job may be done through the definition of the parameters of data to be stored, data description and a series of combinations of individual information in order for duplicated or unwanted data not to be stored in the ERM. There should also be an overload alert, which has to alert the ERM when there is no available space for new data to be stored. In such a case, the ERM should assess the situation in terms of the space required. Once space is found, the ERM should allocate the job of data storage to the next available resource. The "Store Collected Data" activity is illustrated in Figure 5.15.

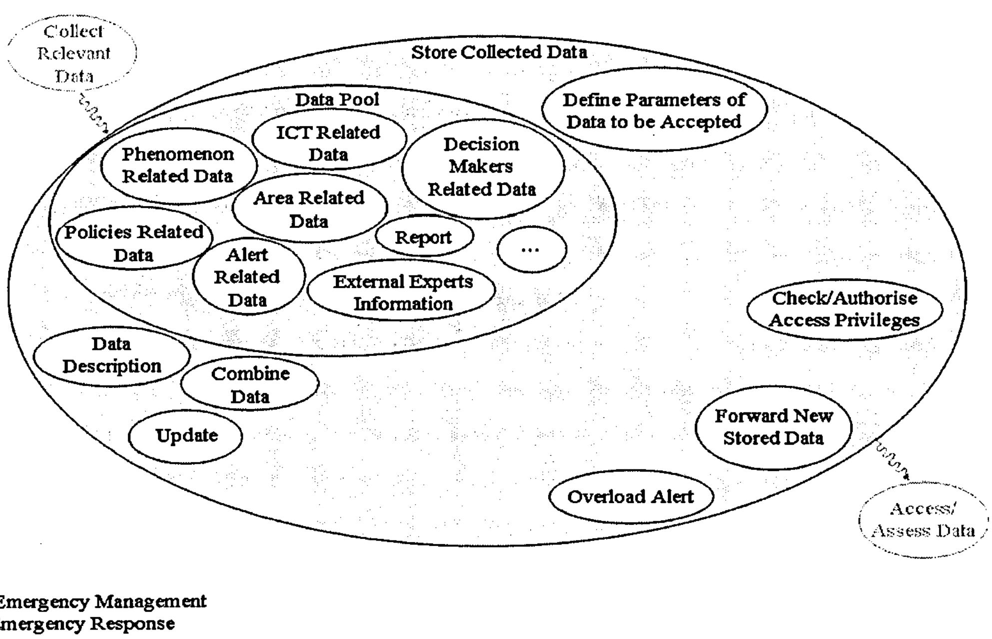


Figure 5.15: Store Collected Data

5.3.4.5 Access/Assess Data

Once the data has been stored using the activities as described earlier, the process of the "Access/Assess Data" activity should take place. The first step of assessment should involve the retrieval of the relevant data, according to the demands and priorities defined by the instrumentation or by the decision makers. This data has to be analysed and combined through the support of a series of decision support tools.

Along with the expertise provided by the decision makers, the ERM needs to generate the relevant course of action. However, it is expected that the ERM should be able to calculate the consequences of the proposed course of action prior to the formation of a final course of action as a method to choose the most appropriate one from a number of alternative solutions.

The result from this activity should be the generation of an alert command, or information, which has to feed the "Decide ER Job Plan" activity. The generated data should be accurate and detailed enough for this activity to create an appropriate job plan.

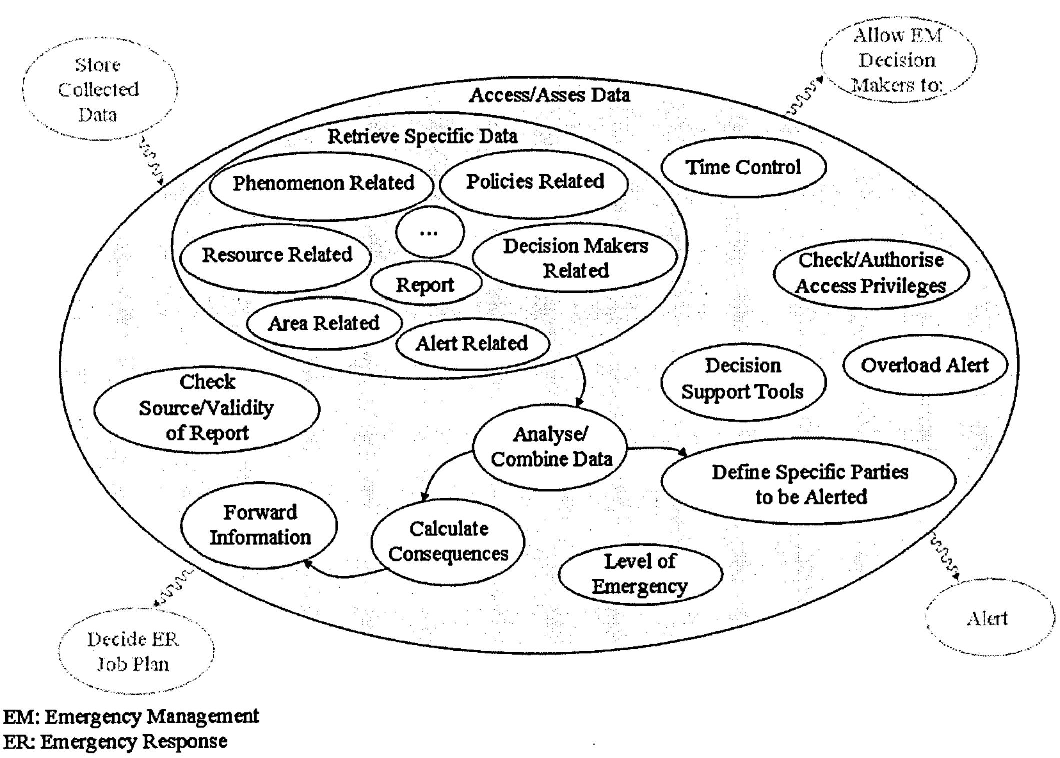
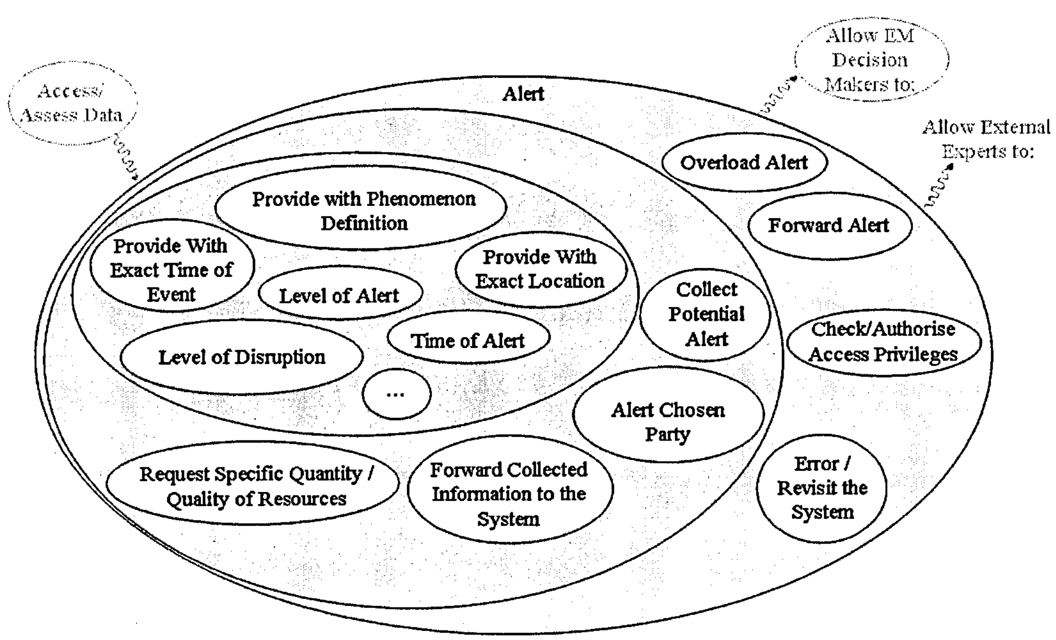


Figure 5.16: Access/Assess Data

The "Access/Assess Data" activity should contain a timer to count the time-related constraints. In the event, that there is a requirement for more computation power to meet time constraints for a certain task during an activity, the infrastructure should identify and re-allocate tasks to other or more available resources. Similarly, the same should happen when the overload alert informs that the computation storage space available is not enough to process and store the remaining or whole data. The processes described above are illustrated in Figure 5.16.

5.3.4.6 Alert

The "Alert" activity as part of the ERM should be initially used after the first flow of information and after the first (automatic) assessment run by the ERM, in order the decision makers to be informed about the occurrence of the natural phenomenon and for potential catastrophic results. It should also be used during the response operation, when the "Access/Assess Data" activity results in the need for more resources for the completion of a specific job plan. In this case, the ERM needs to alert the decision makers that the available resources are not enough to cover the demands and therefore, that they need to re-run the assessment process to generate an alternative solution. This may involve the use of the externally available resources or a request for support from other neighbouring available analogous ERMs. These actions should take place through the use of the "Request" activity of the model, which is described in Section 5.3.4.7.



EM: Emergency Management
ER: Emergency Response

Figure 5.17: Alert

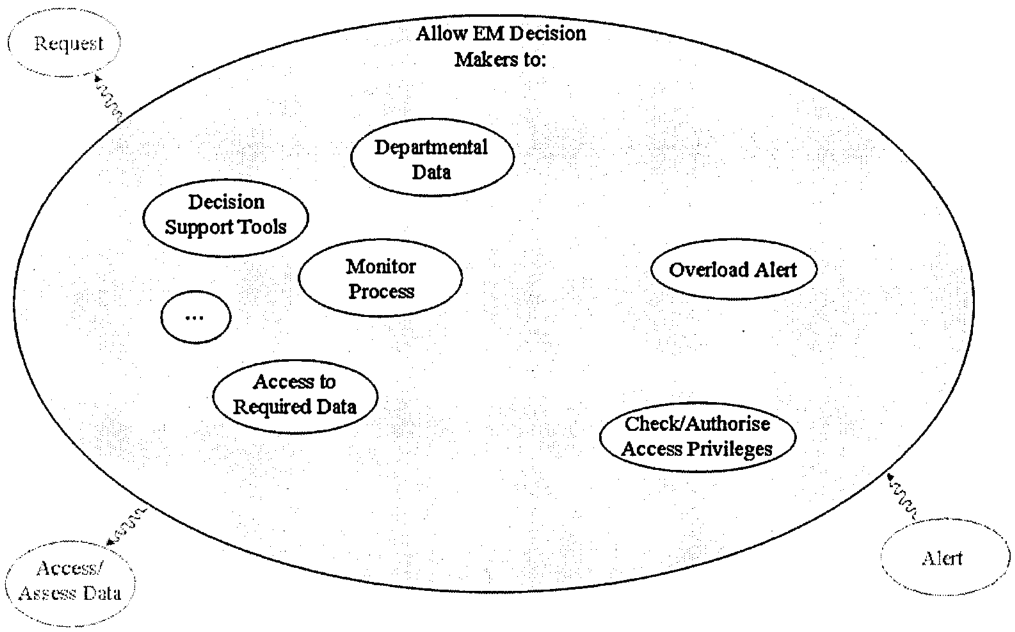
The function of "Alert" may also be used when operational units report a job failure, a need for more resources or when an error or a conflict occurs within the ERM. This may be a failure of a specific instrument, a power network failure, a phone line failure, an overloaded part of the ERM, or any other potential cause. In this situation, the ERM should alert the decisions makers and through the "Report" activity should inform them of what caused the alert situation. Figure 5.17 demonstrates the "Alert" function of the ERM.

5.3.4.7 Allow EM Decision Makers to:

All the functions of the ERM must be monitored by the decision makers through the use of their specific parts, which are described in this Sub-section. Each authority's leader should have access to the ERM, via the "Allow EM Decision Makers" activity.

The activity has to allow the decision makers to use their personal computers located in their offices, portable devices including PDAs and any other audiovisual equipment registered with the ERM to log-in to it. Leaders of the police, fire and rescue, health service, emergency management, municipality and county departments should be able to use this facility to run a virtual meeting during the decision making process. For example, the meeting between the decision makers is considered very essential part of the response phase. Currently, these meetings are limited to physical ones. Current processes do not support virtual meetings with access at the same time to individual records, as well as a holistic view of the operation. The proposed model should allow enough computation power to sustain a video-conference meeting and open access for each participant to their own resources which will add to the holistic view of the operation.

By far, this method is considered a significantly more efficient and effective manner of collaboration. Leaders will have the ability to inform the assessment of the collected data, as well as request other relevant data or instrumentation, or to request support from external experts and their analogous leaders of the neighbouring municipalities or counties (depending on the hierarchy). Figure 5.18 illustrates the decision makers' part of the proposed ERM.



EM: Emergency Management
ER: Emergency Response

Figure 5.18: Allow EM Decision Makers to

5.3.4.8 Request

The "Request" activity could be used by the decision makers or by the external experts. According to the results of the assessment process they may request external assistance, more resources, re-assessment of a situation, or any specific data they consider essential. "Request" should collect the demand, and then it should assess it and categorise it according to the predefined categories. Finally, it should forward the request to the "Use/Provide Currently Available Resources" activity of the ERM for processing. Then, the ERM should run its activities as normal, collecting this data, storing it – according to the "store collected data" activity – assessing it and finally, ERM should take any appropriate action.

The "Request" activity is demonstrated in the following Figure 5.19.

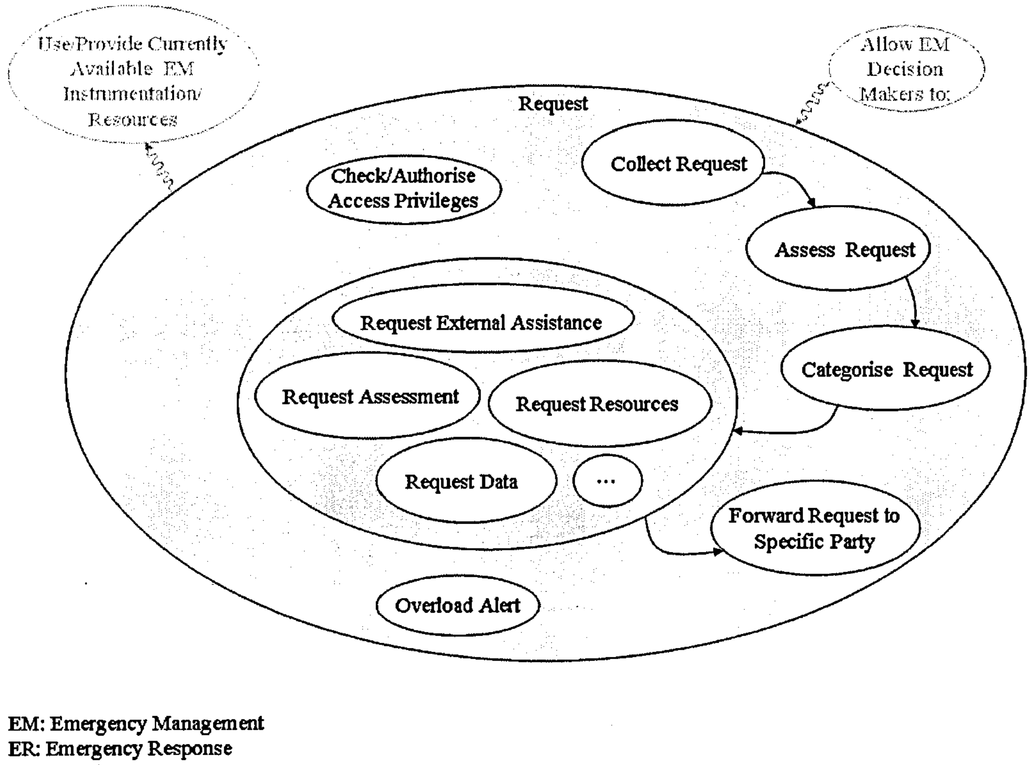


Figure 5.19: Request

5.3.4.9 Decide Emergency Response (ER) Job Plan

The decision on an ER job plan follows the assessment of the collected data activity. During this process the ERM needs to retrieve the relevant stored data, to employ the emergency plans and with the support of the assessment about the current situation to decide and formulate a specific job plan. The job is defined in terms of location, number of people, other resources or instruments needed, expertise required and time constraints. In addition to these, the ERM has to establish the relationships and hierarchy of the parties involved in the specific job plan.

As in all parts of the proposed conceptual model, this one should be able to provide those responsible for emergency response authorities with room to add any other essential function during the creation of the manifestation. This process is illustrated in Figure 5.20.

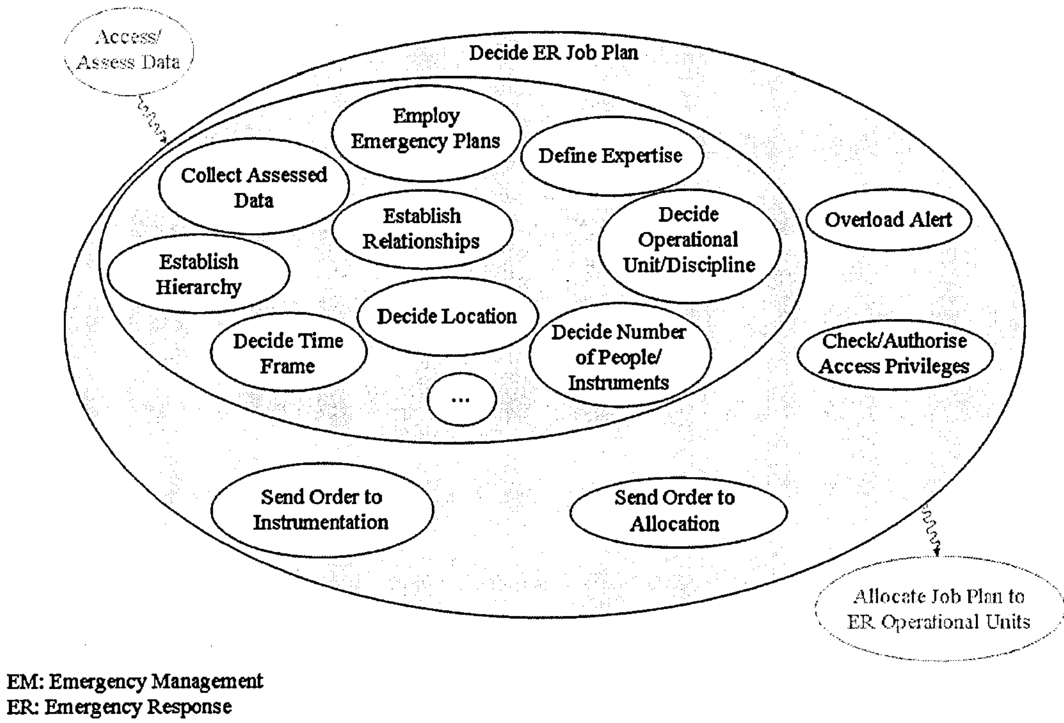
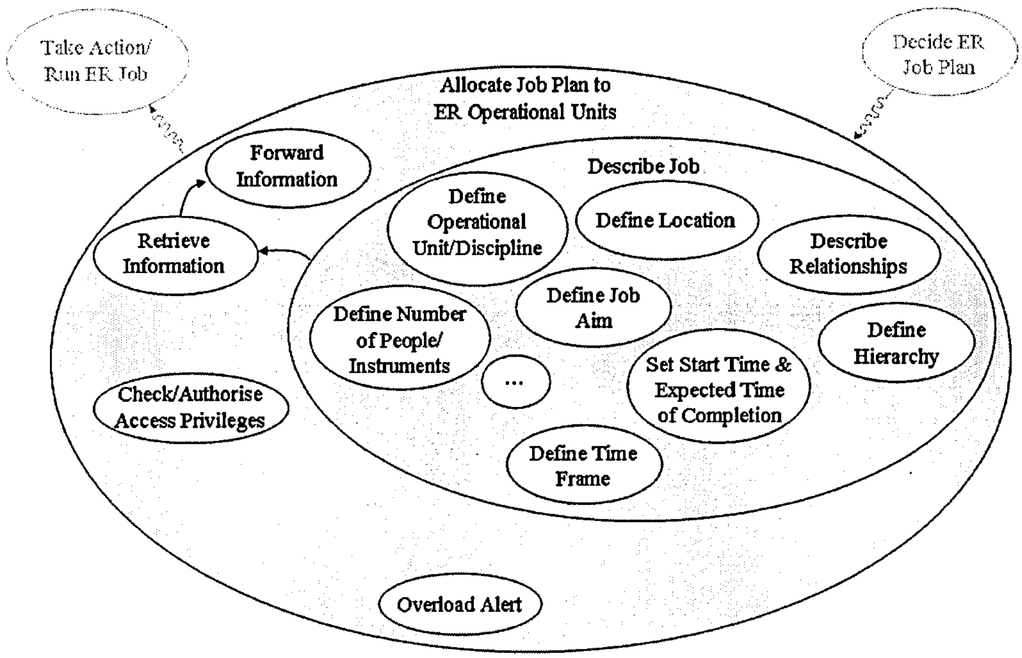


Figure 5.20: Decide ER Job Plan

5.3.4.10 Allocate Plan to Emergency Response (ER) Operational Units

The "Allocate Job Plan to ER Operational Units" activity is the part of the ERM, which should be accessible by the operational units, either humans or instruments. At this stage the ERM should have the ability to locate the selected unit by the "Decide ER Job Plan" function and to allocate to it the particular job. The job plan has to contain the description of the job ordered to be executed by the specific unit in terms of the location, ordering of the exact start time and time limit. It should also provide information relevant to the identification of the unit to take action and a clear definition of the aim of the job.

The allocation of the job has to reach the relevant operational unit through a series of instruments, which need to be connected to the main proposed ERM. These may include computers, PDAs, VHF radios, telephones or any other instrument that may be supported by the model's infrastructure. The "Allocate Job Plan to ER Operational Units" process is illustrated in Figure 5.21.



EM: Emergency Management
ER: Emergency Response

Figure 5.21: Allocate Job Plan to ER Operational Units

5.3.4.11 Take Action/Run Emergency Response (ER) Job

The function following the allocation of the job plan is the "Take Action/Run ER Job" activity. If the job is allocated to human-based resources this part of the ERM should only count the time during the action and keep the job "open" until it receives from the unit the report about the status of the job. However, when the time limit for this particular job expires and the unit has not reported anything back yet, the ERM needs to warn the unit about it. When the operational unit reports the status of the job including completion or termination for any reason, this part of the ERM should stop the counting process.

If the job is allocated to some kind of instrument, such as computers, this part of the ERM has to locate and compile the hardware defined by the "Allocate Job Plan to ER Operational Units" activity and to order them to run the job. During the run of the job it should count the time, monitor the progress of the job and the status of the instruments involved waiting for the final report, which is described in the following sub-section. This process is graphically described in Figure 5.22.

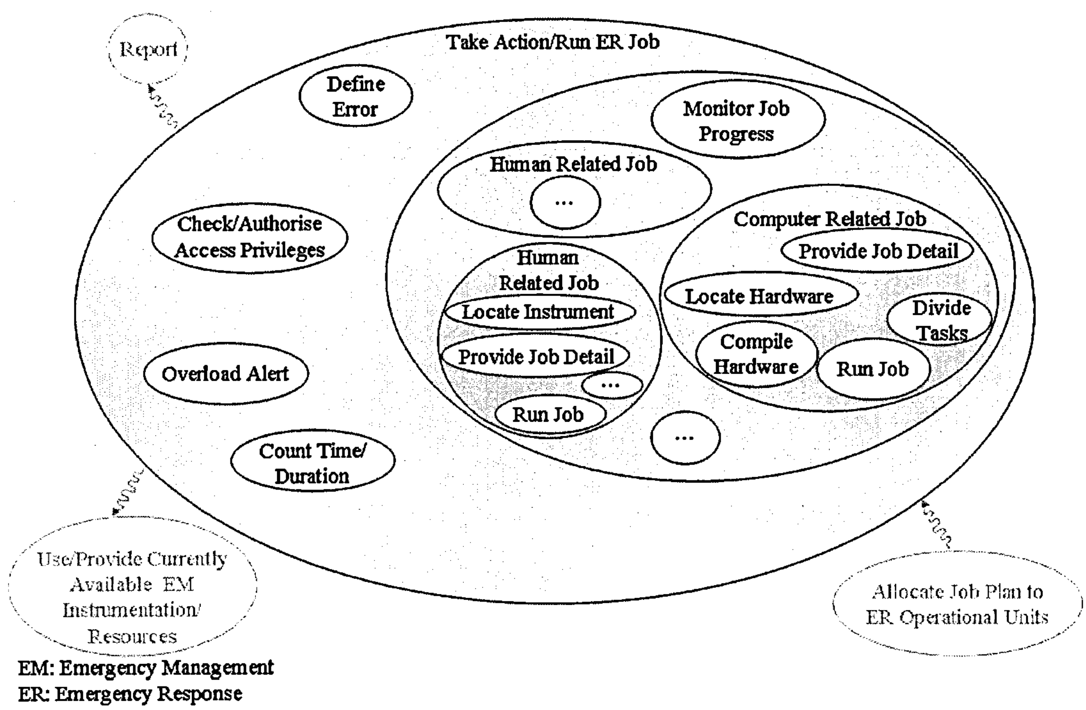


Figure 5.22: Take Action/Run ER Job

5.3.4.12 Report

This activity of the ERM should be used by the operational units and the instrumentation to which the job plans have been allocated during or after job completion in order to report their status back to the ERM.

According to current practice, there may be three different categories of reports, namely the completed jobs, the jobs in progress and the job failures. When the job is completed the leader of the operational unit has to inform the ERM about the time of completion, the results, the status of the team members and the status of their tools/instruments. In this case, after the collection and storage of the report, the unit should be considered an available resource and ready for the next job allocation. When the job is in progress the leader of the unit should send a report either if there is an unexpected parameter/problem, which causes conflicts and does not allow the completion of the task, or if there is need – according to his assessment – for more resources to overtake the job. In both situations the report needs to be collected and stored by the ERM and the unit should receive new orders of actions through the allocation of job plan coming up by the assessment process. Finally, the leader of the operational team has to report the failure of an allocated job, along with the reason of failure, time, status of his resources/team and any unexpected conditions the unit met during their action towards the specific task. This report should also be collected and stored and its information submitted to the assessment process, in order for an alternative/new job plan to be decided for the specific situation.

The above process should take place even if the operational unit consists of instruments. In these situations the leading computer may be responsible for reporting the status of the allocated job. A decision tree diagram related to the process of reporting a job status is presented in Figure 5.23.

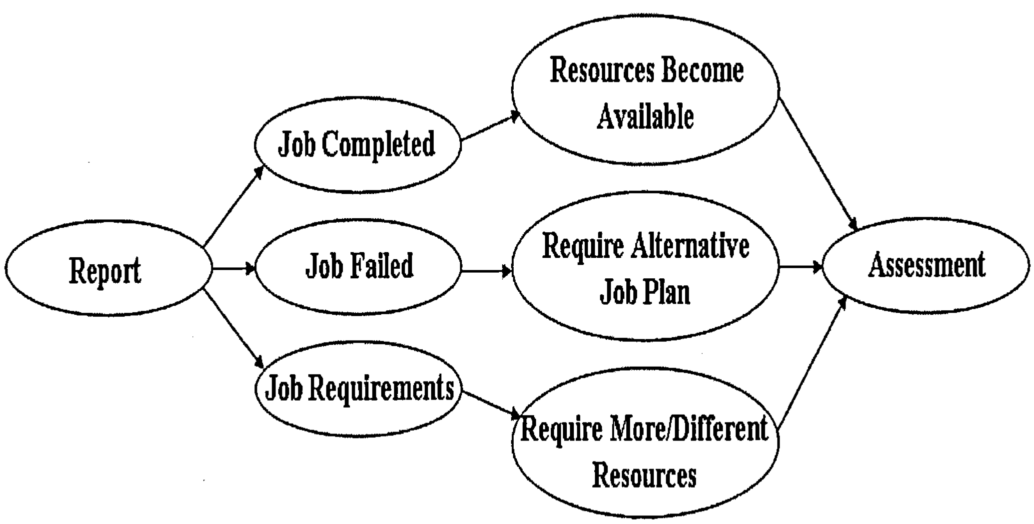
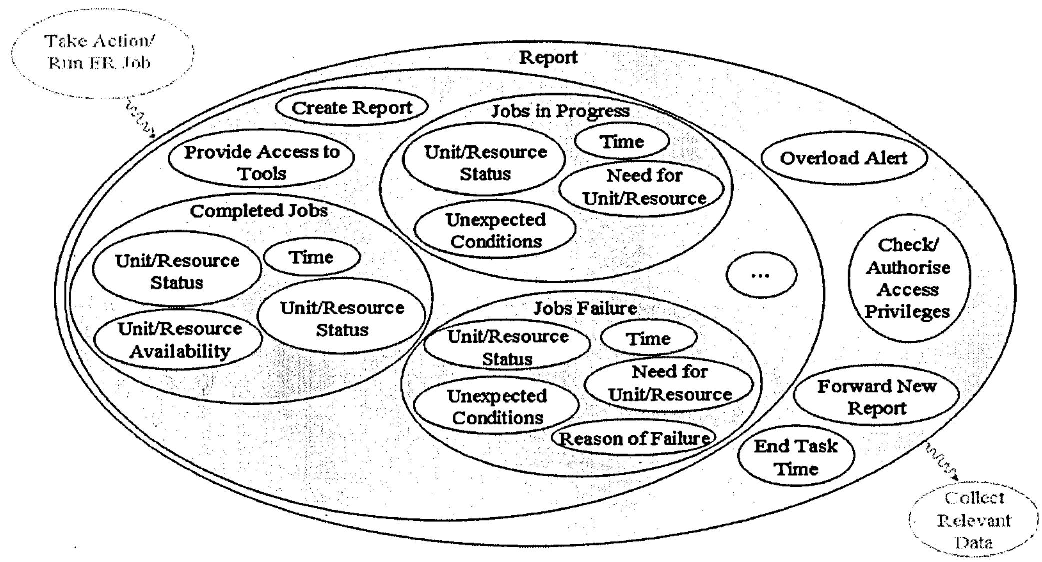


Figure 5.23: The Report Process

Figure 5.24 is a graphical representation of the "Report" function of the ERM.



EM: Emergency Management
ER: Emergency Response

Figure 5.24: Report

5.4 Comparing the Proposed Conceptual Model with Perceived Reality

This section is concerned with a comparison of the proposed conceptual model with perceived reality. According to SSM epistemology, comparison of the conceptual model with perceived reality involves the examination and the identification of its activities in terms of:

- Whether they exist or not in the real world;
- In what form they exist in real world;
- In what systems they exist in real world; and
- Whether the activities that exist in the real world are good or bad.

According to Checkland and Scholes (1991), the ways for this step to be carried out include informal discussions, formal questioning, scenario writing based on operating the models, and trying to model the real world in the same structure as the conceptual model. Although the latter is considered as by far the most common technique (Checkland and Scholes, 1991), it is believed that at this stage the "scenario writing based on operating models" method is the most appropriate for comparing the model with perceived reality. Using this method the processes of the conceptual model are compared with real world, and the demands of the technological support needed for achieving the full potential of the model are acknowledged.

Therefore, the following sub-sections are concerned with the examination of the above issues using findings from the literature review, the case studies and the structured interviews, which were held with emergency management stakeholders, as presented in Chapter 4 and further analysed via the use of SSM.

5.4.1 Examination of Whether the Conceptual ERM's Activities Exist or Not in the Real World

Findings extracted by the literature review, the case studies and the one-to-one structured interviews with the emergency management stakeholders show that the activities of the proposed conceptual model exist in real world practice of emergency response operations. The main activities of the model include the following:

- Use / Provide Currently Available Emergency Management Instrumentation / Resources;
- Collect Relevant Data;
- Store Collected Data;
- Access / Assess Data;
- Alert;
- Allow Decision Makers to;
- Request;
- Set Policies;
- Decide Emergency Response Job Plan;
- Allocate Job Plan to Emergency Response Operational Units;
- Take Action/Run Emergency Response Job;
- Report;

In order for emergency management bodies to run a real world operation they have to know the availability and the status of the relevant resources, in order to be able to use them. They also collect all the relevant data about the phenomenon and the situation it has caused and they store it. Then, the decision makers access this data, assess it, decide the job plans and they allocate them to the relevant operational units. The operational units taking the appropriate actions run the job and they report back the completion or failure of the assigned job.

Findings suggest that during/after the occurrence of an extreme phenomenon all the parties involved in emergency management are alerted about its occurrence, in order to be ready to assess the situation and take part in any response operation needed. In conclusion, according to the emergency management experts who took part in the interview exercise, all the activities of the proposed conceptual model exist in the real world. However, there is no evidence that they exist in a single system.

5.4.2 Examination of in What Form the Conceptual ERM's Activities Exist in Real World

Although the above section provides evidence that the proposed conceptual model's activities exist in the real world, the question that it raises, according to the methodology's epistemology, is in what form they exist and this is examined next.

Findings, as discussed in Chapter 4, suggest that during the occurrence of an extreme natural phenomenon in an area the first information about the phenomenon reaches the emergency management operation centre by fax, e-mail, or telephone from the relevant body (earth observation centre, weather station, etc.) after 20 to 25 minutes. The emergency managers of all the authorities involved arrange a physical meeting in the operation centre. The operational units are usually first informed about the situation through the emergency calls of the affected people and they first reach the affected area to support the victims, without a specific job plan in the first instance. At the same time they feed updated information about the situation to the emergency managers by the use of mobile phones and VHF radios. Decision makers collect, store and assess this information and along with the data provided by the scientific bodies about the actual phenomenon they then take decisions about the job plans and they feed the operational units with them, using the same means of communication presented above. However, there are concerns about the accuracy of the information as it is processed in oral form and the time frame in which the communication between decision makers and operational units takes place.

Concluding this section and based on the primary findings, all the activities of the conceptual model seem to exist in the real world. However, the forms in which they exist cause concerns and do not allow for the accurate, safe and timely fashioned completion of the response operation.

5.4.3 Examination of in What Systems the Conceptual ERM's Activities Exist in the Real World

The series of structured interviews carried out in Greece and the England have suggested the type of systems in which the above activities of the proposed conceptual model exist in the real world.

As an example, consider the occurrence of an earthquake. In this situation the earth observation centre provides the emergency operation centre with many details about the earthquake produced by high quality instruments and using cutting-edge technologies. However, the means used to transfer this information to the operation centre include fax machines, e-mails, landlines and mobile phones. The information transferred is related to the time, place, magnitude, and geological aspects of the phenomenon. However, emergency management stakeholders point out that this kind of data is not of much support for the response operation as they are not provided with any indication of the scale of disruption in the affected area.

In addition to the above, the leading authorities do not use the full potential of modern instrumentation to support their processes. One of the most important factors of an emergency operation is the continuous communication of up-to-date information and decisions. In the real world, this process takes place through the use of telephones (landlines, mobile or satellite), e-mails, fax machines and VHF radios.

Most of these means of communication involve oral communication; therefore there are concerns about the accuracy of the information transferred. In addition to this, there are no alternative solutions in the cases of instrumentation failure. Finally, another important limitation as stated by the emergency management stakeholders is the distributed and incompatible systems each department uses to store or assess data. They stated that there is no single complete and compatible system to accommodate all the needs of the decision makers and the operational units during the process of an emergency response operation.

5.4.4 Examination of Whether the Conceptual ERM's Activities that Exist in the Real World are Good or Bad

Findings drawn from the literature review and the interviews, performed with the emergency management stakeholders pointed out a number of problems associated with practices undertaken during response operations. However, these are not related to the activities themselves, but to the forms in which these activities exist and to the systems that host them.

Emergency management stakeholders find the process of the physical meeting they have to run as a time-consuming method and a method that does not allow them to have access to important data and people in their departments. Another very important constraint they have mentioned is that the form of information which reaches the operation centre is paper-based or in oral form. Thus, they need to document it before trying to access and assess them. In situations when they need to run a computer-based application, the activity becomes harder and more time-consuming as they need to transform the data into an electronic form. Another limitation is that the job plans are transferred to the operational units through means supporting oral communication, such as VHF radios and mobile phones and this leads to misunderstandings. In addition, there is no complete system to accommodate the process and the results of past operational exercises, which may be used in future response operations as guidelines, or even during re-evaluation of emergency plans, or in emergency personnel training exercises.

In concluding this section, it can be said that the activities employed to respond in an emergency situation caused by the occurrence of a natural disaster have been assessed as acceptable by the emergency management stakeholders. However, they are dissatisfied with the forms in which activities are undertaken.

According to the output of the primary research tools, the present study considers the activities, which are followed by emergency management stakeholders during response operations, as given. Experts who participated in the interview exercise have pointed out that the activities of the ERM exist in the real world in one way or another. Findings suggest that there is no a system consisting of all activities in a single entity, as well as that there is the need for a single system to accommodate them. Clearly, the approach of the proposed conceptual model to facilitate emergency management stakeholders with an up-to-date picture of what is currently available about the situation concerned will increase possibilities for a better solution to be encountered. The forms in which the model's activities appear and operate should support the distributed nature of emergency response management to further support current practice, in terms of effectiveness and efficiency. The study illustrates a proposed conceptual model of how to accommodate all the processes and needs of decision makers, operational units and instrumentation during response operations in one model. However, there is still the need for the investigation of the appropriate technological infrastructure to support this model in real-world manifestations, according to the above-mentioned demands. Therefore, it has to be a technology capable of incorporating different types of data, software and hardware; capable of running parallel and highly demanding jobs; and to work in a timely and dynamic fashion to support the collaborative nature of stakeholders to plan, control, coordinate and communicate activities related to the emergency response operations. The potential information and communication technologies to support the proposed conceptual model are investigated in Chapter 6.

5.5 Summary

Chapter 5 has analysed and investigated the problems in managing emergencies as presented in Chapter 4. In particular, primary and secondary research findings were further analysed and integrated using SSM epistemology. The method led to the formulation of a conceptual model with a particular reference to emergency response management operations for natural disasters. The proposed model has been compared with perceived reality and the findings revealed that although the activities of the models exist in the real world, the forms in which they exist and the fact that they do not exist in a single ERM causes problems during the response operations. Finally, the Chapter has concluded by clearly identifying the need for incorporating the proposed model with an appropriate computerised infrastructure that is able to accommodate the collaborative nature of the defined emergency response management procedures in such a way that will overcome current ICT limitations.

The following chapter (6) presents a review of emerging Information and Communication Technologies that can potentially be incorporated into the conceptual SSM-Based Emergency Response Model.

Chapter 6 Enabling Grid Technologies

6.1 Introduction

The findings in Chapter 5 highlighted a number of concerns in relation to the Information and Communication Technologies (ICT) used for the purpose of managing emergency situations in the real world. This chapter starts by introducing the ICT evolution. Most importantly, it makes reference to appropriate technologies, which have emerged to support situations in similar scenarios. With this in mind, it also describes the latest cutting edge developments in relation to the Grid and its enabling technologies, as the most appropriate technology for the problem addressed in the present study. On this basis, it presents some current real-world Grid applications and explores whether Grid technology could be used within the emergency response management. This involved one-to-one structured interviews with Grid technology experts. Finally, overall conclusions related to the applicability of Grid technology are made through the integration of findings from the literature review and from the interviews made with emergency management stakeholders and Grid technology experts.

6.2 The ICT Revolution

Advances in computer networking technologies have been predominant in our society and have caused the need for people to work electronically (Gentzsch, 2001). Webopedia (2004) defines a network as a group of two or more computer systems linked together. According to the geographical distance between them, networks could be categorised as local area networks (LANs), wide area networks (WANs), campus area networks, metropolitan area networks and home area networks. A LAN is defined as a dedicated data communications network that links computers and their peripherals for the purpose of exchanging information, programs, and other resources (Mirabito, 1994). A LAN is a self-contained network, in which computers are geographically close together, usually in a single office or building (White, 1998). However, one LAN can be connected to other LANs over any distance via telephone lines and radio waves. A system of LANs connected in this way is called a WAN (Webopedia, 2004).

Overall, networks are used to allow users to share their resources towards the achievement of a goal. One of the most well known networks is the Internet, which refers to the physical structure of computer networks (Brown and Honeycutt, 1997). In the mid-1960s the Internet 'was built mainly to provide scientists with an infrastructure for faster communication via e-mail' (Gentzsch, 2001). In the 1990's, 'the "Hypertext Transfer Protocol" (HTTP) allowed users to link any two documents and a vast, online library-cum-shoppingmall called the World Wide Web (WWW) exploded across the Internet' (Kulikauskas, 2003).

Advances in science and other disciplines have been made possible largely through the collaborative efforts of many researchers in a particular domain. In turn, collaborative work using computing technologies enabled people in dispersed environments to work together towards the achievement of a common goal. For example, Deelman et al (2004) point out that 'we see collaborations of hundreds of scientists in areas, such as gravitational-wave physics, high energy physics, astronomy and many others coming together and sharing a variety of resources within a collaborative manner in pursuit of common goals'.

In this context, resources located in dispersed environments are called distributed resources (Joseph et al, 2004; Connolly and Begg, 2002; Rob and Corronel, 2004) while 'technologies supporting distributed resource exchange, such as communication, collaboration and co-operation, are known as distributed technologies' (Wulf, 2003). A distributed system containing different hardware and software working together in a co-operative manner to solve a problem is called heterogeneous (Burback, 1998).

Distributed collaborative working utilising ICT requires and caused continuous developments in computing technologies. Among others, references to that have been made by Anumba et al, 2003; Antonioletti et al, 2003; Brezany et al, 2003; Foster and Kesselman 2004; Foster et al, 2001; Mann, 2003; and Waters et al, 2004. As an example, Foster et al (2001) describe a scenario which requires imagining that you are the head of an emergency response team that is trying to deal with a major chemical spill. According to this scenario, you will probably want to know things like: What chemicals are involved? What's the weather forecast, and how will that affect the pattern of dispersal? What's the current traffic situation, and how will that affect the evaluation routes? Apparently, such an advanced collaborative environment may require exploitation of combined resources, but most importantly, these resources are distributed in nature and they may consist of people, scientific instruments, computer-based and network resources, applications, and various datasets.

Similarly, many scientific communities require the analysis of large datasets for solving many interesting scientific problems (Mann, 2003; Brezany et al, 2003). The datasets addressed by individual applications are very often heterogeneous and geographically distributed and are used for collaboration by the communities of users, which are often large and also geographically distributed. An issue often encountered in heterogeneous distributed systems, including the Internet and the WWW is resource incompatibility (Gravano et al, 1997).

Hence, 'the ability to make data stores interoperable remains a crucial factor for the development of this type of collaborative systems' (Wohrer et al, 2004). One of the remaining challenges for such facilitation is that of data integration, which aims to provide seamless and flexible access to information from multiple, autonomous, distributed and heterogeneous data sources through a query interface (Ullman, 1997; Calvanese et al, 1998; Levy, 2000; Castillo et al, 2004). However, the combination of large dataset size, geographic distribution of users and resources, and computationally intensive analysis results in complex and stringent performance demands that, until recently, have not been satisfied by any existing computational and data management infrastructure (Foster and Kessleman, 2001).

In tackling these problems, the latest developments in relation to networking and resource integration have resulted in the new concept of Grid technology, a term originally coined by Foster in 1995. Grid computing addresses the issue of collaboration, data and resource sharing (Kodeboyina and Plale, 2003; 2004) in a more effective and efficient manner. In particular, Grid computing has been developed 'as a method to increase global collaborations based on their shared resources' (Fox, 2003), as well as to provide an infrastructure 'which supports the execution of large scale, resource-intensive, distributed applications' (Berman et al, 2003). This is due to the 'fast emerging "Grid protocols", which might allow users to link almost anything else; databases, simulation and visualisation tools, even the number-crunching power of the computers themselves' (Kulikauskas, 2003). On this basis, the following sections aim to further discuss issues related to the cutting edge technologies associated with the emerged Grid concept and its standards.

6.3 The Grid Concept

Grid technology or Grid computing are terms used interchangeably (Foster et al, 2001) and refer to an emerging infrastructure designed to enable the flexible, secure, co-ordinated sharing of processing power, data or other types of resources to be used for large-scale and/or intensive problem solving purposes among a dynamic collection of resources including individuals or teams. Moreover, Grid technology have been described as the 'infrastructure and a set of protocols to enable the integrated, collaborative use of distributed heterogeneous resources including high-end computers (also referred as nodes), networks, databases, and scientific instruments owned and managed by multiple organisations, referred to as Virtual Organisations' (Foster, 2002).

A Virtual Organisation (VO) is formed 'when different organisations come together to share resources and collaborate in order to achieve a common goal' (Foster et al, 2002). In this context, resource sharing is highly controlled, with resource providers and consumers defining clearly and carefully just what is shared, who is allowed to share, and the conditions under which sharing occurs. A set of individuals and/or institutions 'defined by such sharing rules (policies) form what is sometimes called a VO' (Foster et al, 2001).

The term "resources" covers a wide range of concepts including physical resources (computation, communication and storage), informational resources (databases, archives and instruments), individuals (people and the expertise they represent), capabilities (software packages, brokering and scheduling services) and frameworks for access and control of these resources (OGSA – Open Grid Services Architecture). Antonioletti et al (2003) describe the terms "databases" and "data resources" as follows: 'Databases refer to systems used for managing structured data, such as relational databases and collections of semi-structured files'. Similarly, the term "data resource" is used virtually synonymously with database, the only difference is that 'it could be considered to include devices, such as telescopes and scanners that produce or accept structured data, or data integration infrastructures that provide the illusion that a single database is being accessed'.

The Grid computing concept has emerged as an important research area differentiated from other computing advances including open systems, clusters and distributed computing. Bessis et al (2007) explain that open systems 'remove dependencies on proprietary hardware and operating systems, but in most instances they are used in isolation. Each deployed application has its own set of servers owned for a particular purpose within the enterprise'. Multiple applications rarely share common servers, resulting in silos of statically linked applications and servers. This configuration results in poor server utilisation.

In contrast, the Grid builds upon open source architectures and addresses the removal of silos within a connected enterprise (Xu et al, 2004). Unlike conventional distributed systems, which are focused on the communication between devices and resources, Grid computing takes advantage of computers connected to a network making it possible to compute and to share data resources. Unlike clusters, which have a single administration and are generally geographically collocated, Grid has multiple administrators and they are usually dispersed. However, the most important feature is that clusters have a static architecture, whilst 'Grids are fluid and dynamic with resources entering and leaving' (Bessis et al, 2007).

The added value that Grid computing provides, as compared to conventional distributed systems, lies in the ability of the Grid to allocate and re-schedule resources dynamically in real-time according to the availability or non-availability of optimal solution paths and computational resources. Should a resource become compromised, untrustworthy or simply prove to be unreliable, then 'dynamic re-routing and re-scheduling capabilities can be used to ensure that the quality of service is not compromised' (French et al, 2007). Finally, the Grid is a type of a parallel and distributed system that enables the sharing, selection, and aggregation of resources distributed across multiple administrative domains based on their availability, capability, performance, cost, and users' quality of service requirements (Goyal, 2005).

6.3.1 Types of Grids

Figure 6.1 and the following paragraphs present the three generic types of Grid, based on descriptions provided by Gentzsch, 2001; Foster, 2002; GRIDtoday, 2003; and Sun Microsystems, 2006.

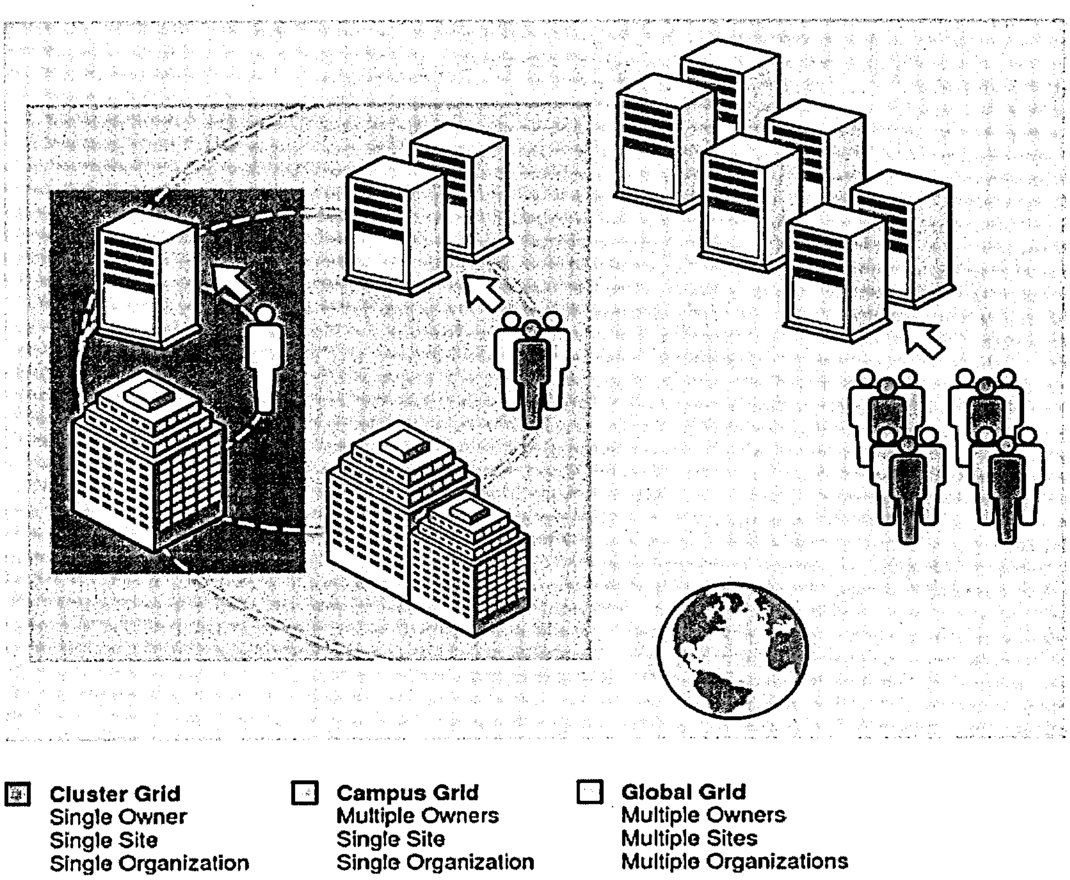


Figure 6.1: Grid Types (source: Sun Microsystems, 2006)

- **Cluster Grid**

This type of Grid includes the local clusters/farms deployed on a departmental or project basis and they refer to one owner. It is used to cluster computing resources within an individual department to ensure maximum up-time and utilisation of available resources. This is something that many organisations have achieved in order to manage and schedule workloads.

- **Campus Grid**

The term "Campus Grid" is defined as the process of merging cluster Grids into one campus or enterprise Grid and it can be used for multiple projects and by multiple owners. Campus Grids could involve distributed applications sharing resources across multiple partners and locations within the same organisation, or collaboration between partner organisations. Campus Grids are considered as the first true stage of Grid deployment, as they involve distributed applications sharing resources across multiple enterprise departments and locations within a single organisation.

- **Global Grid**

This type refers to the creation of one single Grid infrastructure across the globe. This can be achieved by merging all campus Grids into a global Grid across organisations in multiple sites. Some may argue that the global Grid seems an over-ambitious manifestation. However, the idea of a single Grid of computing resources spanning the globe, into which users dip via the WWW to make use of the available processing power would be of great benefit.

6.3.2 The Grid Architecture

The Grid architecture organises components into five layers as shown in Figure 6.2. It is important to note that the components within each layer share common characteristics, but they can build on capabilities and behaviours provided by any lower layer. These five layers, as identified by Foster et al (2001), are 'the application, collective, resource, connectivity and fabric layers'. The following descriptions are drawn from research work presented by Foster et al, 2001; 2002; 2004; Antonioletti et al, 2003; 2004; and Bessis and Wells, 2005.

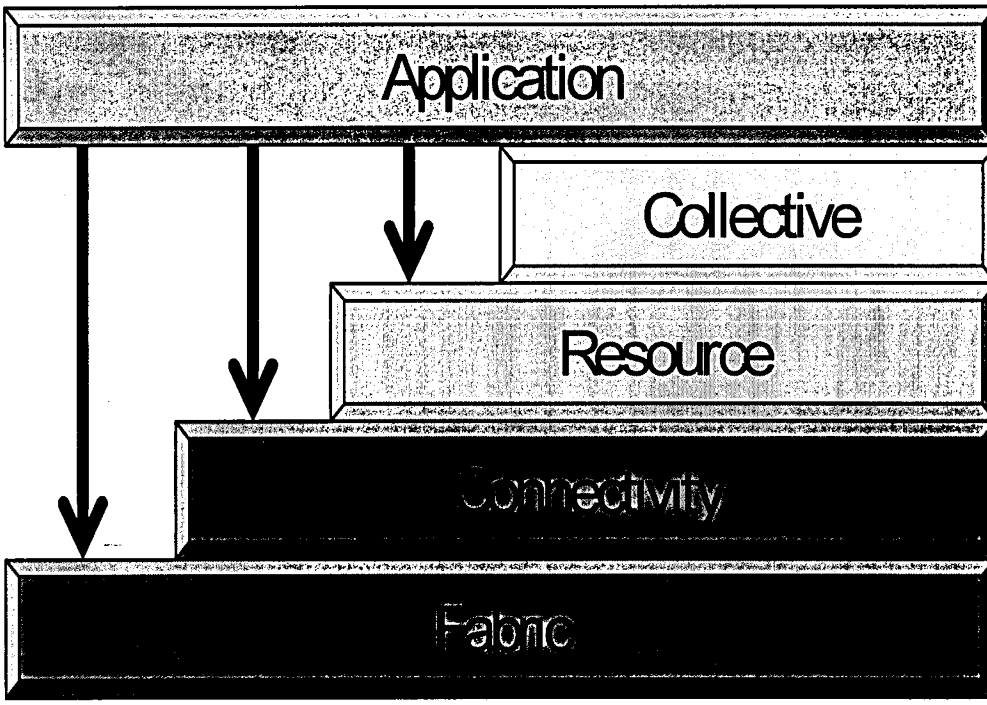


Figure 6.2: The Grid Layers (source: Foster and Kesselman, 2004)

- **The Application Layer**

The application layer comprises the end-user interface, which provides access to services, such as shared resources in a Grid environment. In this respect, an application may call upon available services defined at any of the lower layers. That is to say, they define protocols in the form of Application Programming Interfaces (APIs), which are implemented by software development kits (SDKs), which in turn use appropriate protocols to interact with Grid system services to provide capabilities to the end-user.

Such an application may allow users to send a highly intensive request over the Grid in order to utilise the processing cycles of idle computing resources, interrogate for a pattern in astronomical radio data, download climate models or even run simulations based on various distributed and heterogeneous datasets, which may be further used for decision-making purposes. Some examples of real-world Grid applications are presented in Section 6.6.

- **The Collective Layer**

The collective layer contains protocols and services that are not associated with any one specific resource. These are global in nature and capture interactions across collections of resources to provide co-ordination between multiple services. It consists of three basic components including the scheduler, the resource broker and the load balancing. Each one of them has its own responsibilities and they all co-operate with each other. The collective layer provides services to implement sharing, such as data replication, scheduling services, directory services and other functions.

The scheduler is responsible for managing jobs, such as allocating resources needed for any specific job, partitioning of jobs to schedule parallel execution of tasks, data management, correlation and service-level management capabilities. The jobs submitted to the Grid scheduler are evaluated based on their service-level requirements and then allocated to the respective resources for execution. The resource broker provides the pairing of services between the service requestor and the service provider. This is illustrated in Figure 6.3.

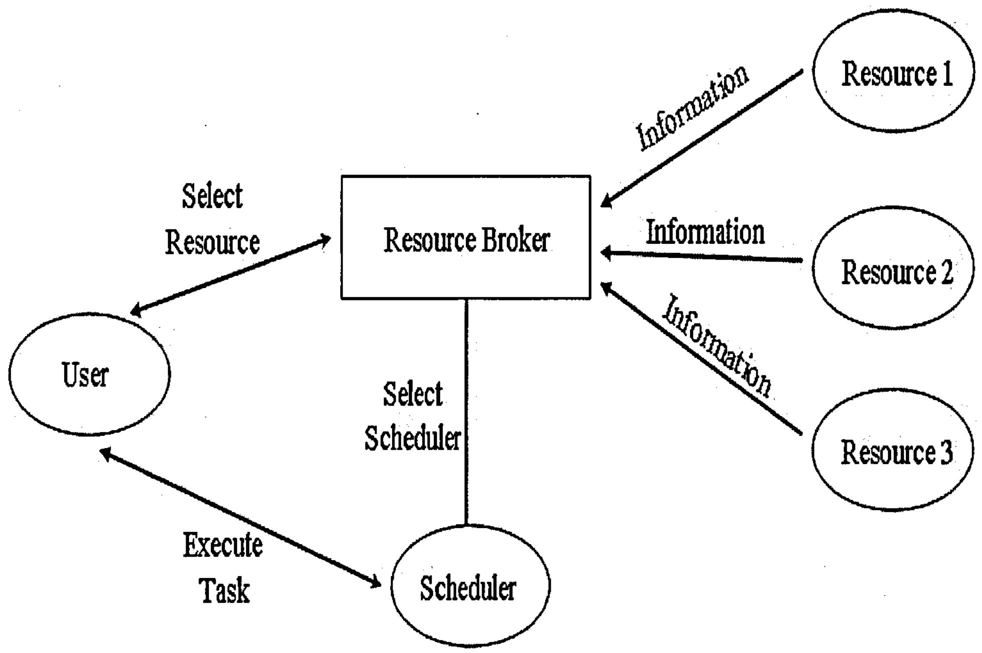


Figure 6.3: Resource Broker (source: informit, 2005).

This pairing enables the selection of the best available resources from the service provider for the execution of a specific task. The resource broker collects information (i.e., resource availability, usage models, capabilities and pricing information) from the respective resources and uses this information source in the pairing process. In general, the resource broker may select the most suitable scheduler for the resource execution task and collaborate with the scheduler to execute the task. During the pairing process, a resource broker is responsible for the allocation of the appropriate resource or a combination of resources for the task execution and for the support of users' constraints, such as deadlines and budget, for optimised scheduling.

The workload can be pushed outbound to the resources, or can then pull the jobs from the schedulers based on the availability state and the resources. This function is known as load balancing and it involves partitioning of jobs, identifying the resources and queuing for the jobs. In some cases resource reservations might be required and there is the possibility of running multiple jobs in parallel. The load balancing also provides support for failure detection and management. In the cases that there is a failure the load distributors are able to redistribute the jobs to other relevant available resources.

- **The Resource Layer**

The resource layer defines how individual resources are connected to and collaborate with the collective layer. This is where the concept starts to move from the distributed environment to the individual resources in the Grid environment. This layer is concerned with obtaining and providing information about the state of a resource and managing that resource. It provides methods for initiation of services, monitoring and control, accounting and in some cases even payment.

The two primary classes of the resource layer protocols include the information and management protocols. Information protocols are used to obtain information about the structure and state of the resource, while the management protocols are used to negotiate access to a shared resource, such as specifying the resource requirements and the operations to be performed.

- **The Connectivity Layer**

The connectivity layer provides the infrastructure with the basic networking facilities to connect the resources together. That is to say, it defines the core communication and authentication protocols required for Grid-specific network transactions. Communication protocols enable the exchange of data between fabric layer resources, while authentication protocols build on communication services to provide the secure, reliable exchange of data between resources. These are both based upon core Internet protocols, such as TCP/IP (Transfer Control Protocol/Internet Protocol) and DNS (Domain Name System).

Security at this layer is built using existing technologies, such as Secure Sockets Layer (SSL), Public Key Infrastructure (PKI) and X.509 Digital Certificates (Foster et al, 2001; Foster et al, 2002). The security functions of the Grid provide facilities such as single sign-on (SSO) delegation of rights and integration with local security.

- **The Fabric Layer**

The final layer is the fabric layer, which represents the interface to the local physical or logical resources themselves, such as disk storage, processors or network interfaces, data resources, directories or code libraries. The Grid is not concerned with the particular details of the fabric, but with the access to these resources in a device-independent manner.

Finally, one of the main keys of the Grid concept is the agreement between VOs, who share some common concerns and requirements that may vary in size, scope, duration, sociology and structure. The members of any VO negotiate the sharing of resources based upon the rules and conditions (known as policies) defined by the VO and the members then share the resources in the VO's constructed resource pool. Foster et al (2004) point out that this 'lead to one of the basic requirements of a Grid system, which is the ability to provide a high-level quality of service (QoS) for end-to-end solutions for users'.

Therefore, QoS validation must exist as a basic feature in any Grid system, as measured by the available resource metrics. These metrics include 'response time measurements, aggregated event performance monitoring and measurements, security fulfilment, resource scalability, availability, autonomic features, fail-over mechanisms and networking services' (Joseph et al, 2004).

6.3.3 Grid Computing Related Technologies

The following sub-sections present Web Services, Open Grid Services Architecture (OGSA), Open Grid Services Infrastructure (OGSI) and a number of middleware, as the current computing technologies used for deploying Grid applications.

Web Services emerged from the business computing world with 'the aim to support business-to-business relationships in a language-neutral, platform independent way' (Antonioletti et al, 2005). However, several shortcomings associated with Web Services made it inadequate for the development of Grid-based applications. Hence, the Open Grid Services Architecture (OGSA), developed by the Global Grid Forum (GGF), aims to define a common, standard, and open architecture for Grid-based applications (OGSA-DAI, 2006). The goal of OGSA is to standardise practically all the services one finds in a Grid application by specifying a set of standard interfaces for these services.

In essence, a Grid Service is simply a Web Service with many extensions that make it adequate for the development of Grid-based applications. However, OGSA's high-level architectural view does not provide enough detail when describing Grid services. Hence, another complimentary standard called the Open Grid Services Infrastructure (OGSI), 'which gives a technical specification of what a Grid service is' (The Globus Alliance, 2006) has been created. The middleware is 'a layer of software that is also required to develop a Grid application' (Baxevanidis, 2002). A number of middleware toolkits are currently used for the development of Grid environments, including the Globus Toolkit, which among others is discussed in Section 6.6.3. Figure 6.4 summarises the involvement and the relationships of these technologies.

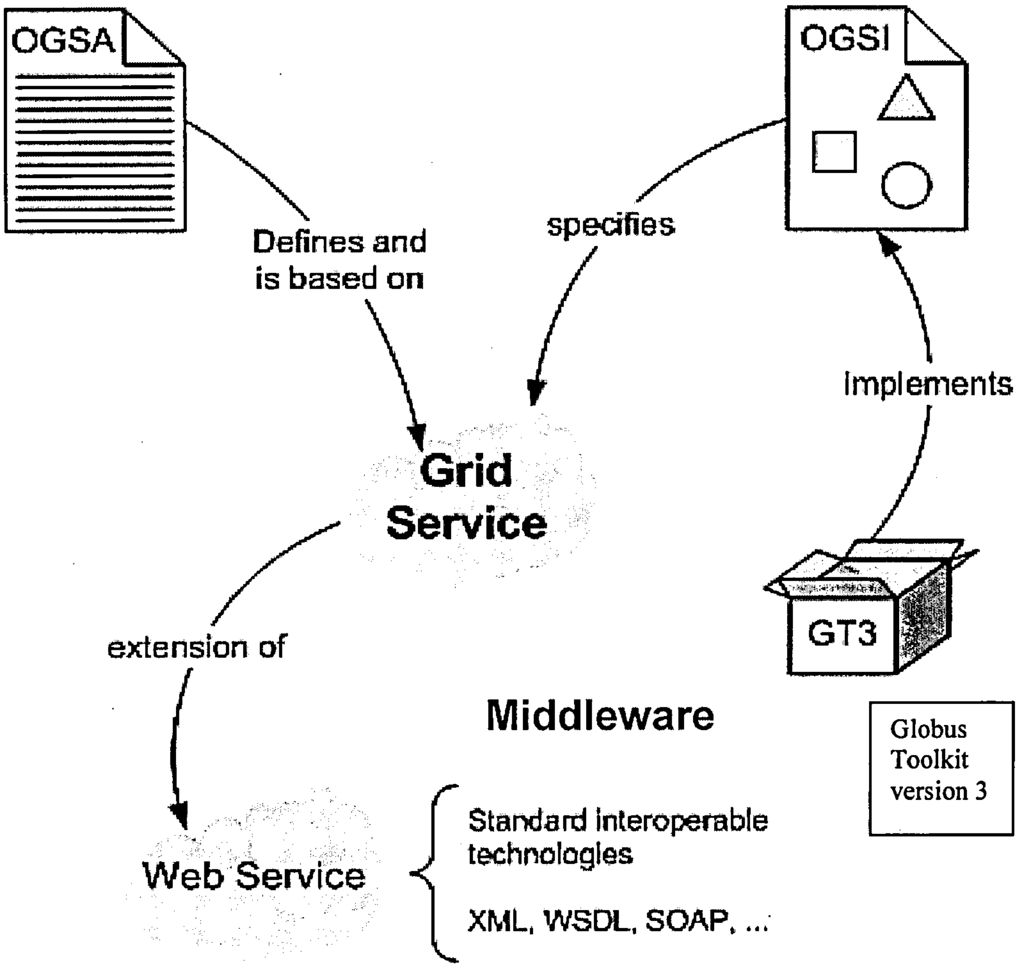


Figure 6.4: Grid Computing Related Technologies (source: The Globus Alliance, 2006)

The following sub-sections describe in greater detail these technologies, as well as the protocols, standards and middleware associated with the development of Grid environments.

6.3.3.1 Web Services

The aim of Web Services is 'to provide a Service-Oriented Approach (SOA) to distributed computing' (Atkinson et al, 2005). They consist of 'loosely coupled, reusable software components that semantically encapsulate discrete functionality and are distributed and programmatically accessible over standard Internet protocols' (Sleeper, 2001). Web Services are 'self-contained, self-describing, modular applications that can be published, located and invoked across the WWW' (Anumba et al, 2003). They aim 'to extend the WWW from an infrastructure that provides services to humans to one that provides services to software looking to connect with other software' (Coyle, 2002). The concept of Web Services is to focus on the specific needs of a particular application without regard to other functions. This concept forms 'a key element of achieving synergistic specificity' (Schilling, 2000).

Web Services are intended to provide users with standard, interoperable means, by which different organisations and individuals can develop software applications as a standard means for heterogeneous systems to share and exchange information (Iyer et al, 2003).

The World Wide Web Consortium (W3C), which aims to develop standards, protocols and guidelines to ensure long-term growth for the WWW (W3C, 2006) points out that 'Web Services provide a standard means of interoperating between different software applications, running on a variety of platforms and/or frameworks'. Its interoperability architecture helps in the 'identification of those global elements of the global Web Services network that are required in order to ensure interoperability between Web Services' (W3C, 2006).

- **Web Services Standards and Protocols**

In terms of standards, Grids share the same protocols with Web Services. As explained earlier, Web Services have been developed to make easier the exchange and sharing of information between heterogeneous distributed systems. The standards, which form the core of Web Services and Grid applications, include Extensible Mark-up Language (XML), Simple Object Access Protocol (SOAP), Web Services Description Language (WSDL) and Universal Description Discovery and Integration (UDDI). In brief, XML is used for data encoding, while the UDDI standard is used to register a service so others can discover it. The WSDL is used to describe how to use a service; and finally, the SOAP standard is used for structuring a message. Figure 6.5 illustrates how these standards inter-operate. A more detailed description of these standards is presented next.

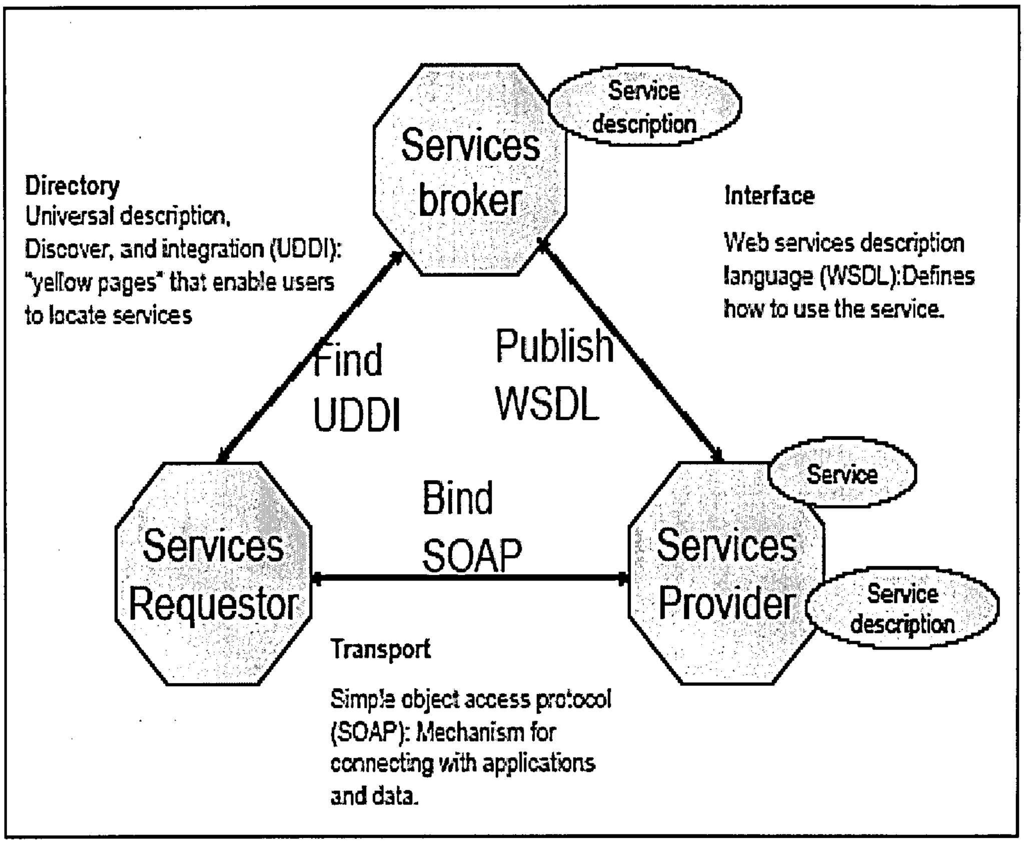


Figure 6.5: Web Services Architecture (source: Iyer et al, 2003)

- **Extensible Mark-up Language (XML)**

Extensible Mark-up Language (XML) is a simple, very flexible text format that 'originally designed to meet the challenges of large-scale electronic publishing' (W3C, 2006). XML is used to build the standards and protocols for higher-level interactions, such as passing messages between systems and it provides essential network services, such as resource discovery. It also provides a machine-independent and human-readable way of storing information. XML is a meta-language, which can be used to define the syntax of other languages. Its main benefit is that it is a widely accepted standard, which provides a platform-independent data exchange mechanism. More information about XML can be found at the World Wide Web Consortium (W3C, 2006).

- **Simple Object Access Protocol (SOAP)**

The SOAP standard provides a basic mechanism for Web Services applications to communicate with each other in order to provide services seamlessly to end-users (Marsan, 2001). Essentially, SOAP is an XML language, which is used to encapsulate XML documents for transmission across the WWW. SOAP serves as a communication protocol between applications. It is a format for sending messages and it is designed to communicate via the Internet. As with XML, SOAP's main advantage is that it is platform-independent. SOAP is a protocol for exchange of information in a decentralised, distributed environment. It consists of a (n):

- Envelope that defines a framework for describing what is in a message and how to process it;
- Set of encoding rules for expressing instances of application-defined data-types;
- Convention for representing remote procedure calls and responses.

- **Web Services Description Language (WSDL)**

WSDL contains details of how to communicate with a remote Web Service. It is an XML format for describing network services as a collection of communication endpoints operating on messages' exchanges. It uses the standard XML schema to describe how to interpret the message and how to contact the Web Services, as well as what protocols to use (W3C, 2006). It also specifies exactly how to interpret the data in the SOAP messages associated with the Web Services. This function is very important, as it helps to avoid the misinterpretation of data between the client and the services. The standard serves as a "recipe" for the automation of the details involved in the communication process of the applications. That is to say, a WSDL document allows the reuse of its elements including:

- Types: a container for data type definitions using some type system;
- Message: an abstract, typed definition of the data being communicated;
- Operation: an abstract description of an action supported by the service;
- Port Type: an abstract set of operations supported by one or more endpoints;

- Binding: a protocol and data format specification for a particular port type;
- Port: a single endpoint defined as a combination of a binding and a network address;
- Service: a collection of related endpoints.

- **Universal Description Discovery and Integration (UDDI)**

UDDI is a group of specifications defining a platform-independent registry service for Web Services. Service providers can use the UDDI registry to publish the services they offer. Service consumers then can use UDDI to discover services that suit their requirements and to obtain the service metadata needed to consume these services (UDDI, 2006).

One important feature of the UDDI specification is that each time that a new or updated version of a Web Service is released, the UDDI registry 'allows the service to be put up to use it immediately without the need of re-integration work' (nwfusion, 2005).

6.3.3.2 Open Grid Services Architecture (OGSA)

The Open Grid Services Architecture (OGSA) 'extends Web Services with consistent interfaces for creating, managing and exchanging information among Grid services, which are dynamic computational artefacts cast as Web Services' (Krause et al, 2002). Similarly to Web Services, the OGSA specifies a Service-Oriented Architecture (SOA) approach. It aims to bridge the divide between Web Services and Grid technology. It is a high-level framework designed to support dynamic VOs to share independently administered data and resources seamlessly across a network of heterogeneous computers (Foster et al, 2002). In describing a Grid Service, Sotomayor (2004) refers to it as being an extension of a Web Service, where services may include computational resources, storage resources, networks, programs, databases, etc. (Foster et al, 2002). From an end-user point of view, OGSA is an API defined in terms of the WSDL, which describes the interaction of Grid components (Ledlie, 2003). Following Foster's model, OGSA attempts to provide a global Grid Services architecture, which is based upon WWW protocols. In Foster's model, OGSA would sit at the "Collective" layer, with Open Grid Services Infrastructure (OGSI) forming part of the "Resource" layer, along with the associated Web Services protocols.

The potential range of OGSA services is vast and currently includes data and information services, resource and service management, and core services, such as name resolution and discovery, service domains, security, policy, messaging, queuing, logging, events, metering and accounting. It has also become increasingly clear that if the OGSA is to support a wide range of communities, then database integration is vital (Antonioletti et al, 2003; 2004; Nieto-Santisteban, 2004; Watson, 2002). On this basis, significant effort has gone into defining requirements, protocols and implementing the OGSA-DAI (Data Access and Integration) specification as the means for users to access databases in Grid environments. This is outlined next.

- **OGSA-DAI (Data, Access and Integration)**

OGSA-DAI (Data, Access and Integration) provides a means for users to Grid-enable their data resources. In particular, the OGSA-DAI service provides a common Grid service access interface to a variety of data resources ranging from relational databases to XML databases and eventually to structured files (OGSA-DAI, 2006). It supports a number of relational databases including IBM DB2, Oracle, MySQL (Structured Query Language), Microsoft SQL and PostgreSQL (OGSA-DAI, 2006).

As a data integration specification, it aims to allow users to specify *what* information is needed without having to provide detailed instructions on *how* or from where to obtain the information. That is to say, a number of mechanisms have been developed including: ability to communicate and interact with each data source as required; ability to specify a query; ability to match and extract queried data from relevant data source(s) (Castillo et al, 2004).

Figure 6.6 illustrates the interactions between OGSA-DAI services over a Grid environment.

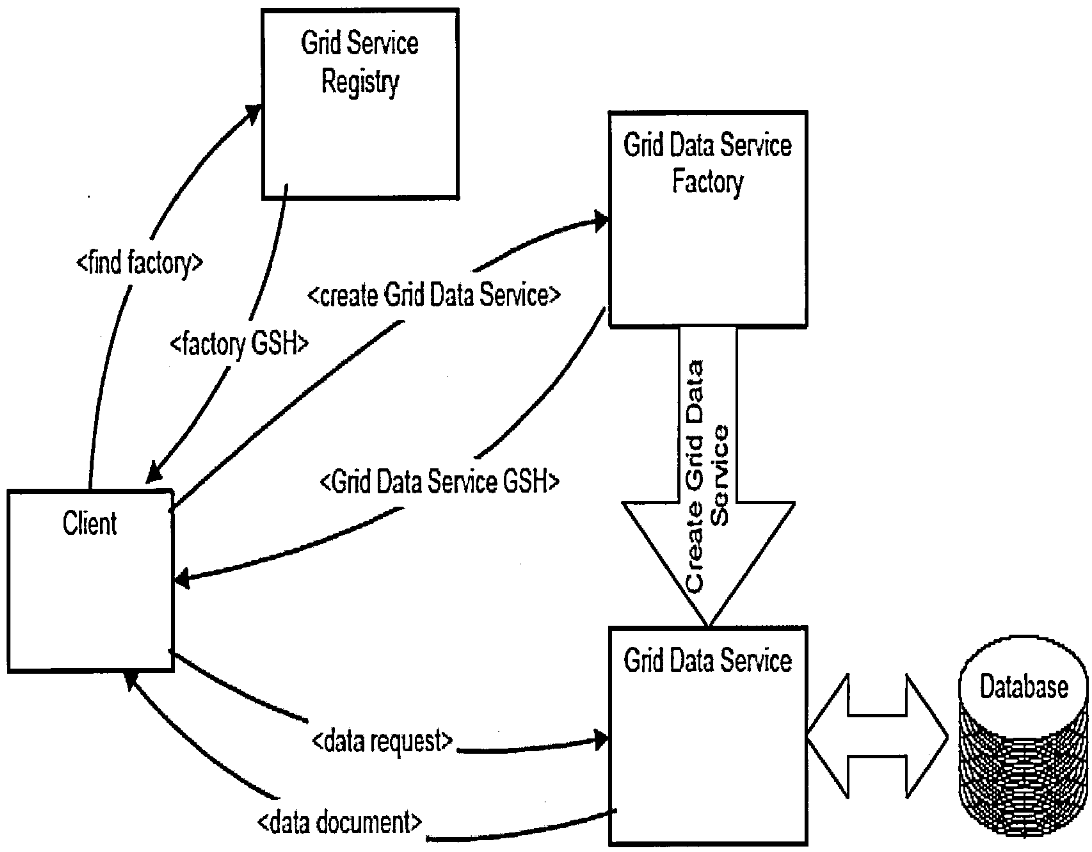


Figure 6.6: OGSA-DAI Services (source: Krause et al, 2002)

A description of how the interactions – illustrated in Figure 6.6 – are envisaged to run is provided (Bann, 2003):

- 1a. A Client sends a request to a Registry, asking for sources of data relevant to "X";
- 1b. The Registry responds with a handle to a Factory;
- 2a. The Client uses the handle to send the Factory a request for access to a database;
- 2b. The Factory creates a GridDataService to manage that database access;
- 2c. The Factory returns a handle to that GridDataService to Client;
- 3a. The Client sends a query (in SQL, Xpath, etc.) to the GridDataService;
- 3b. The GridDataService interacts with the database to have the query executed;
- 3c. The GridDataService returns the query results to the Client in XML.

Finally, newer developments in the area have led to more sophisticated data integration capabilities using Distributed Query Processing (DQP). DQP works as a layer on top of OGSA-DAI, which allows queries to be applied to various XML and relational data resources as though they were a single logical resource (Antonioletti et al, 2005).

- **Open Grid Service Infrastructure (OGSI)**

This is a low-level framework to provide a detailed, formal and technical specification of what a Grid service is. OGSI conforms to a set of conventions (interfaces and behaviours) that define the way in which a client interacts with a Grid service. These conventions along with other OGSI mechanisms associated with the Grid service creation and discovery provide the controlled, fault-resilient and secure management of the distributed and often long-lived state that is commonly required in advanced distributed applications (Ren et al, 2005).

However, the most recent developments (The Globus Alliance, 2006) 'in middleware remove the need for OGSI by implementing another new standard, the Web Services Resource Framework (WSRF)'. This will mean that Grid services (as defined by OGSA) will be implemented directly on top of Web Services.

6.3.3.3 Grid Middleware Toolkits

The following sections are concerned with the toolkits used in the development of Grid environments. These include Globus, UNICORE and Condor, which are described below.

- **The Globus Toolkit**

The Globus is 'a toolkit developed by the Globus Alliance' (The Globus Alliance, 2006). It consists of a set of services, which can be used together or individually to build a Grid environment based on the requirements of the applications needed to be run on the Grid. The services that are provided by Globus include a resource allocation manager, a monitoring and discovery service and storage management services. Each service provides an API, which allows applications to be developed taking advantage of these services.

Although Globus provides a solid foundation for building Grid Services, it does not provide a complete Grid "solution". It has been criticised for having a steep learning curve (schopf02grids, 2005; Ercim, 2005). However, other specialists in the area, such as Kulikauskas (2003), believe that 'Globus is an open-source implementation of Grid protocols that has become the *de facto* standard. Such protocols promise to give home and office machines the ability to reach into cyberspace, find resources wherever they may be and assemble them on the fly into whatever applications are needed'.

- **UNICORE**

UNICORE (The UNICORE Forum, 2006) is an initiative to provide seamless, secure and intuitive access to heterogeneous computing resources (Erwin, 2005). It is built upon UNIX computers, with both UNIX and Windows client applications. UNICORE does not depend upon any specific Grid implementation and it has a modular architecture.

It provides a service, in which the users are able to write applications, which will be run on the system and submit these applications, with job control handled automatically. The actual jobs are written in a native format and are run as processes under the user's local system identification (ID) in the local environment. Therefore, UNICORE does not work as a Grid Service as it is not abstract from the underlying hardware and the user needs to be aware of this aspect when developing applications. It is characterised as a specific implementation of a Grid-based system with operating system-like features. Therefore, there are attempts through the Grid Interoperability Project (GRIP), 'to achieve interoperability between the UNICORE and the Globus toolkits' (Grid-interoperability, 2006).

- **Condor**

Condor is a job scheduler for a distributed environment and 'it aims to develop, implement, deploy, and evaluate mechanisms and policies that support High Throughput Computing (HTC) on large collections of distributive owned computing resources' (Condor, 2007). It can be configured to use the idle time from workstations and submitted jobs can be moved around as machines become available. This function happens transparently and the users do not need to modify their source code. Condor is capable of executing any unmodified binary code on the target system. Although it is not a Grid system itself, Condor can be used to provide a Grid environment with the resources stretching across the boundaries of the organisation. Moreover, Condor has extensions to work together with other Grid middleware such as Condor-g, which allow it to manage Globus resources.

Condor is best suited for the coarse-grained applications, where communication between processes is either limited or does not exist. The user submits the job to Condor via a command-line programme and Condor schedules the job for execution in a traditional UNIX queue-like manner. All the jobs that are in the queue can be queried for information about their state and an e-mail is sent to the job originator on completion of the job.

6.3.3.4 Programming Environments

There is a wide choice of operating systems available to build Grid environments. The main contenders are UNIX/Linux and Windows. Both platforms have their advantages and disadvantages. The reasons for choosing one platform over another include 'the system performance, the ease of implementation and finally, the cost' (Baker et al, 2000). The architecture of the operating system must not be allowed to influence the design or implementation of the system, as portability should be maintained as a key consideration. The choice of programming languages that can be used to implement Grid applications is wide open. It is feasible for applications to be developed in Java, Perl, C or C++. Different Grid applications can be written in different languages; however the choice may be restricted and driven by the choice of the Grid toolkit or server environment in order for the application to be supported.

6.4 Enabling Technologies for the Grid

Previous sections have provided several definitions in relation to the Grid concept and its associated standards. These highlighted the fact that Grid technology as a framework aims to increase global collaboration between interested parties in the form of VOs. That is to say, the need for 'a framework where users, content providers and network operators can interact in the seamless, transparent sale and delivery of a wide range of services' (D'Antonio et al, 2004). Clearly, the issues and the challenges associated with these needs led to the development of the Grid concept as the way of embedding a number of emerging technologies into it.

Apparently, a number of distributed resources need to be shared so others can remotely access and exploit them. The collaboration needs of a VO are not limited to data or processing power, but include other type of resources such as databases, files, software, hardware, or even instruments such as satellites, seismographs, detectors and PDAs. For example, 'data can be streamed in from sensors, stored in large files, produced as a visualisation or science output of a program, or stored in databases' (Fox, 2004).

The combination and integration of all available technologies together will serve as an integrated solution in a dynamic collaborative distributed electronic environment. It is important to note that Grid technology aim to embrace a number of emerging technologies – not to replace them – with the aim of enabling the coordinated use of the VO's existing resources and their underlying emerging technologies. That is to say, by bridging resources, such as data repositories and their data together, it will allow relevant VOs and decision makers to collaborate towards the accomplishment of their common goal. To achieve this, a number of technologies are involved. For example, the use of the Semantic Web will enhance data definitions and with the combination of Intelligent Agents and Data Mining tools will filter and assist in identifying resources in a more effective and efficient way. Similarly, the use of Web Services will assist in monitoring what resource is currently available, accessible, under what conditions and overall in conjunction with Decision Support Systems will enhance the capability of co-ordinating and managing resources in a timely and less critical fashion. Data then can be visualised and simulated for further work via the use of advanced visualisation systems for ease of use and understanding.

The following sub-sections briefly present emerging core technologies, which when brought together can enable and support the collaborative and dynamic nature required in a Grid environment. Emerging technologies under discussion include the Semantic Web, Intelligent Agents, Decision Support Systems, Wireless Communication and Advanced Visualisation Systems and these are briefly presented next.

- **Semantic Web**

Currently the WWW uses HyperText Mark-up Language (HTML) to display graphics and text over a browser, but does not lend any meaning to the content it describes. The Semantic Web aims to make the WWW more effective for the user by endowing metadata with machine processed semantics. It is focused 'on extending the ability of the WWW by developing standards and tools, which allow meaning to be added to the content of web pages' (Berners-Lee and Miller, 2004). According to the W3C (2001) the vision of this emerging technology is 'to create a universal medium for the exchange of data by allowing meaning to be given, using tools and tags, to the content within web pages'. Berners-Lee and Miller (2004) further support this by pointing out that 'the idea is to have data on the WWW defined and linked in a way that can be used by machines, not just for display purposes, but for automation, integration and reuse of data across various applications'.

The Semantic Web is an extension of the current WWW, in which information is provided with well-defined meaning, enabling computers and people to work in better cooperation. It intends to create a universal medium for information exchange by giving meaning, in a way which will be understandable by computers, to the content of documents on the WWW. It will be able to semantically link various resources, such as documents, images and people amongst others. This characteristic provides 'the capability to move from the current WWW of simple hyperlinks to a more expressive semantically rich WWW' (Hendler, 1999). The Semantic Web uses technologies such as XML, Web Ontology Language (OWL) and Cascading Style Sheets (CSS).

- **Intelligent Agents**

Intelligent Agents (IA) are used extensively on the WWW and they refer to programs that perform tasks, such as retrieving and delivering information and automating repetitive tasks. Wooldridge et al (1995) and Bui and Lee (1999) define an agent as a self-contained program capable of controlling its own decision making and acting based on its perception of its environment, in pursuit of one or more objectives.

Hendler (1999) has described agents as 'a vision of IA on the WWW using the analogy of travel agents'. In particular, rather than doing everything for a user, the agents would find possible ways to meet user needs, and offer the user choices for their achievement. Some IA are also used as 'tools to track WWW behaviour' (Sheshagiri et al, 2004), as they can even watch the users as they browse web-pages and record how often they visit certain sites. They are also used to download favourite sites automatically, let the users know when their favourite site has been updated, and even tailor specific pages to suit user requirements.

IA could also work in a parallel and collaborative way formed on sets of agents or multi-agent systems (MAS). That is to say, each agent is given a discrete task. They then work together to establish which agent will carry out each task, and how they will merge the information they collect the presentation to the user. During this process, agents may 'share knowledge and learning experiences in the process' (Shang et al, 2001). These concepts are important as 'MAS act collectively as a society and collaborate to achieve their own individual goals, as well as the common goal of the society they belong to' (Anumba et al, 2003).

- **Decision Support Systems**

Scott-Morton first articulated the concepts of Decision Support Systems (DSS) in the early 1970s under the general term of Management Support Systems (MSS). Further work on "bounded rationality" by Simon (1977) and "classification types of DSS" by

Keen and Scott-Morton, 1971; Alter, 1980; and Holsapple and Whinston, 1996 have led to the understanding that DSS is a set of concepts associated with supporting the decision-making process via the use of appropriate resources. These '(resources) may include but are not limited to users, data, models, software, and hardware' (Bessis et al, 2007).

Cognitive limitations alongside computer-based developments in computational science including data mining, data visualisation, intelligent agents, artificial intelligence, and neural networks (Maracas, 2002; Turban and Aronson, 2001) have facilitated decision makers with numerous of tools to support operational, tactical and/or strategic level of enquiries within the environment of an organisation. One of the purposes of these technologies is to form appropriate computerised environments in order to provide decision makers with a holistic view, and hence 'the ability to analyse data derived from a collection of multiple dispersed and potentially heterogeneous sources' (Han, 2000).

Apart from supporting business operations (Poess and Floyd, 2001) DSS are widely used for medical purposes (Zupan et al, 2001), risk management (Chrysoulakis and Prastacos, 2001) and emergency situations (Bravata et al, 2004; Padmanabhan et al, 2006; Kozal et al, 2004).

- **Wireless Communications**

Wireless is a term used to describe telecommunications, in which electromagnetic waves (rather than some form of wire) carry the signal over a part of or the entire communication path. Some monitoring devices, including 'intrusion alarms, employ acoustic waves at frequencies above the range of human hearing; these are also sometimes classified as wireless' (Techtarget, 2004). The first wireless transmitters went on air using radiotelegraphy, the Morse code, in the early 20th century. Later, as modulation made it possible to transmit voices and music via wireless, the medium came to be called radio. With the introduction of television, fax and data communication, and the effective use of the abilities of wireless technology, the term wireless has been advanced.

Some examples of current wireless equipment include cellular phones, Global Positioning System (GPS), cordless computer peripherals, cordless telephone, two-way satellite and others (Wang et al, 2004). The goal of wireless communication is to allow the user to access the capabilities of the global network at anytime without regard to location or mobility (Murray, 2003).

- **Advanced Visualisation Systems**

Visualisation systems that are 'currently in use support collaborative, multi-user, virtual reality and Internet technologies' (Anumba et al, 2003). Data visualisation refers to 'the technologies that support visualisation and sometimes interpretation of data and information at several points along the data processing chain' (Turban and Aronson, 2001). The primary goal of visualisation technology is to make it easier for people to understand and use vast amounts of data. According to Marakas (2002) 'data visualisation is very powerful, because the human visual cortex dominates human's perception', as well as because the process of converting objects into information occurs very quickly.

The aim of information visualisation is to create visual representations of abstract data that may have no natural visual representation. Because of this, 'information visualisation requires an additional step in the application architecture to create a visual metaphor to derive meaning from the raw data' (Curington, 1998). An information visualisation application is a software system that uses information visualisation techniques. Advanced visualisation techniques are used in astronomy, geographical information systems (Borodin et al, 2006) and weather forecasting and finally in image processing for medical information systems (Gomez et al, 2002).

6.5 Implications and Challenges in the General Use of Grid Technology

One of the most notable benefits in using Grid technology is that they attempt to provide a homogeneous, reliable, distributed, parallel computing environment across heterogeneous, unreliable, partially connected commodity computing platform in a transparent manner. In doing this, the possibilities for solving previously intractable problems due to the sheer amount of resources available are created (Kramer et al, 2004).

Another obvious benefit is that Grids can improve the response times for the users who are running a given task. With many processors working on a problem, the time taken to perform a task can be significantly reduced. The fact that Grids can use many different types of machines is another important factor. Cheap commodity hardware can be used to construct a Grid, providing a price/performance ratio, which supercomputers and even clusters cannot match. The use of the otherwise wasted processor cycles on desktop workstations also provides users with a cheap source of computing power (force10).

However, there are a number of concerns associated with Grid technology. These involve problems inherited from the computing environments. For example, many authors including Gentzsch, 2002; Abbas, 2003; Baxevanidis, 2002; D'Antonio, 2004; Ferrari and Giacomini, 2004; Foster, 2002; and Joseph, 2004 point out that the concept of on-demand resource sharing includes problems associated with the interaction within the human activity system and hence, they involve resource ownership, security, billing, accounting, usage metering, scalability and open-ended integration. Hence, assigning users, resources and organisations from different domains to a VO remains one of the key technical challenges in Grid computing today.

6.6 Current Grid Applications

The Grid concept has been created in order to serve high demand advanced science and engineering applications. In particular, Baxevanidis et al (2002) point out that 'the term of Grid technology has been coined to denote applications involving resource sharing and co-ordinated problem solving in multi-institutional settings'. This description encompasses a wide variety of scenarios, and indeed Grid computing concepts and technologies have been motivated by, and are being applied within, numerous different domains.

Grid as an emerging technology has been mainly adapted by the research and academic communities around the world, and lately by the governmental bodies of some countries, such as the UK. In particular, 'the UK research community is engaged by a series of pilot projects, which have as their aim to deliver innovative solutions to real-world requirements in engineering, physics, medicine and the environment' (Newhouse, 2002). These projects try to employ Grid technology through a multi-disciplinary approach. This approach is called e-principle and currently, there are many activities which support it. In the particular context of the UK this is called e-Science. These projects develop Grid-based infrastructures 'to meet the diverse requirements of science and their research communities, as well as for governments, health and social sector' (e-Science, 2003). Some disciplines that currently develop Grid applications include:

- Medical/Healthcare (imaging, diagnosis and treatment);
- Bioinformatics (study of the human genome and proteome to understand genetic diseases);
- Nanotechnology (design of new materials from the molecular scale);
- Engineering (design optimisation, simulation, failure analysis and remote instrument access and control);
- Natural resources and the environment (weather forecasting, earth observation, modelling and prediction of complex systems).

Probably the best-known Grid application is the "search for extra-terrestrial intelligence" project called SETI@home, overseen by the University of California at Berkeley (setiathome, 2004). This application networks together computers from around the world running operating systems such as Linux, UNIX and Windows. Around 5 million people in more than 200 countries participate in this activity and they have downloaded a screensaver that makes their computer available, when it is sitting idle, to process radio signals gathered from outer space.

Figure 6.7 demonstrates the SETI@home architecture.

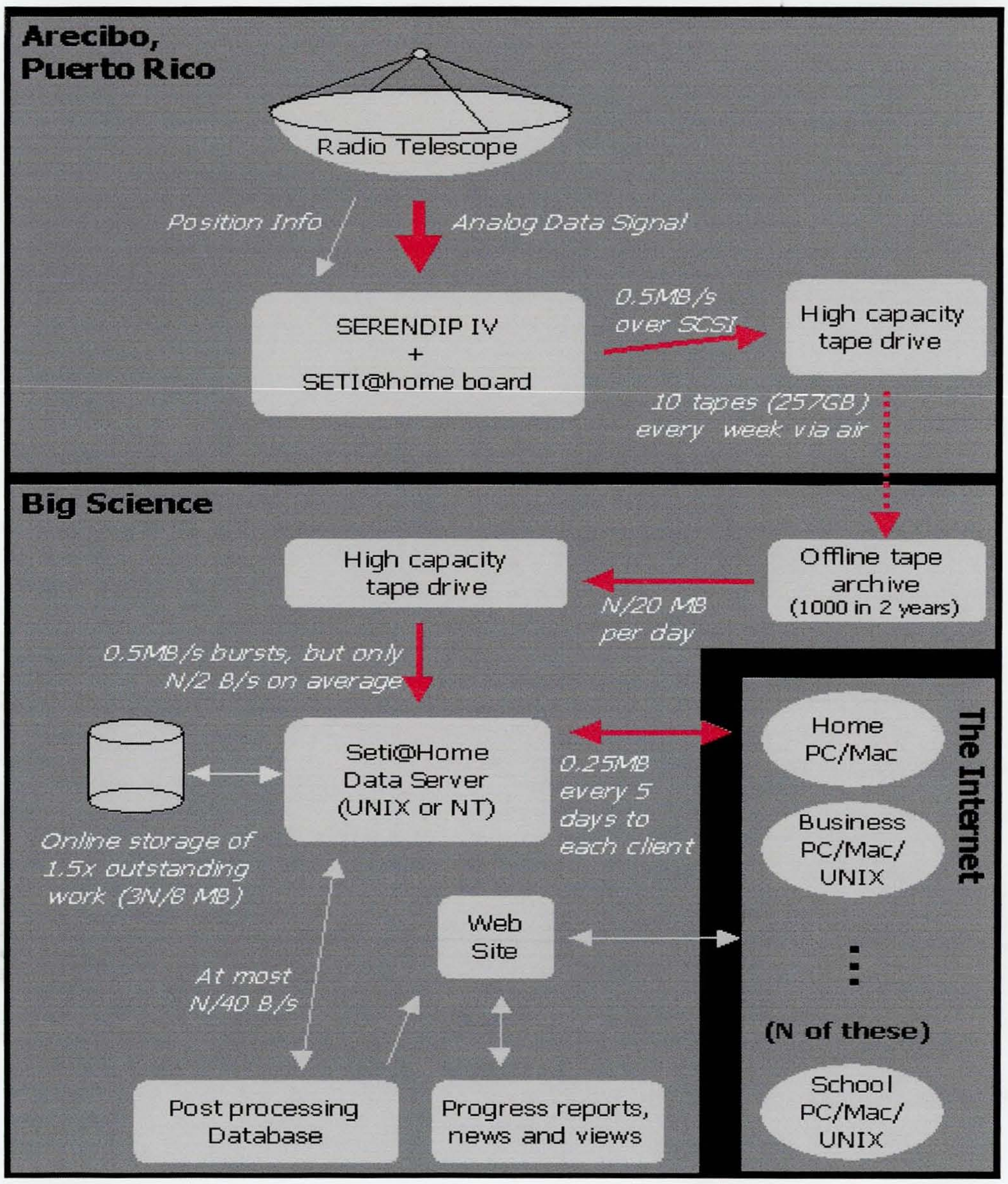


Figure 6.7: SETI@home Architecture (source: SETI@home, 2006)

Grid technology is also 'used for more earth-bound purposes including Bio-technology, Nano-technology, Environmental Technology, Space Technology and Traditional Technology' (Gridcenter, 2005). The following sections present some examples of recent Grid applications and projects.

- **The Access Grid**

The Access Grid (AG) is an ensemble of resources including multimedia large-format displays, presentation and interactive environments, and interfaces to Grid middleware and to visualisation environments. These resources are used to support group-to-group interactions across the Grid. For example, the AG is used for large-scale distributed meetings, collaborative work sessions, seminars, lectures, tutorials, and training. Figure 6.8 represents the Access Grid architecture.

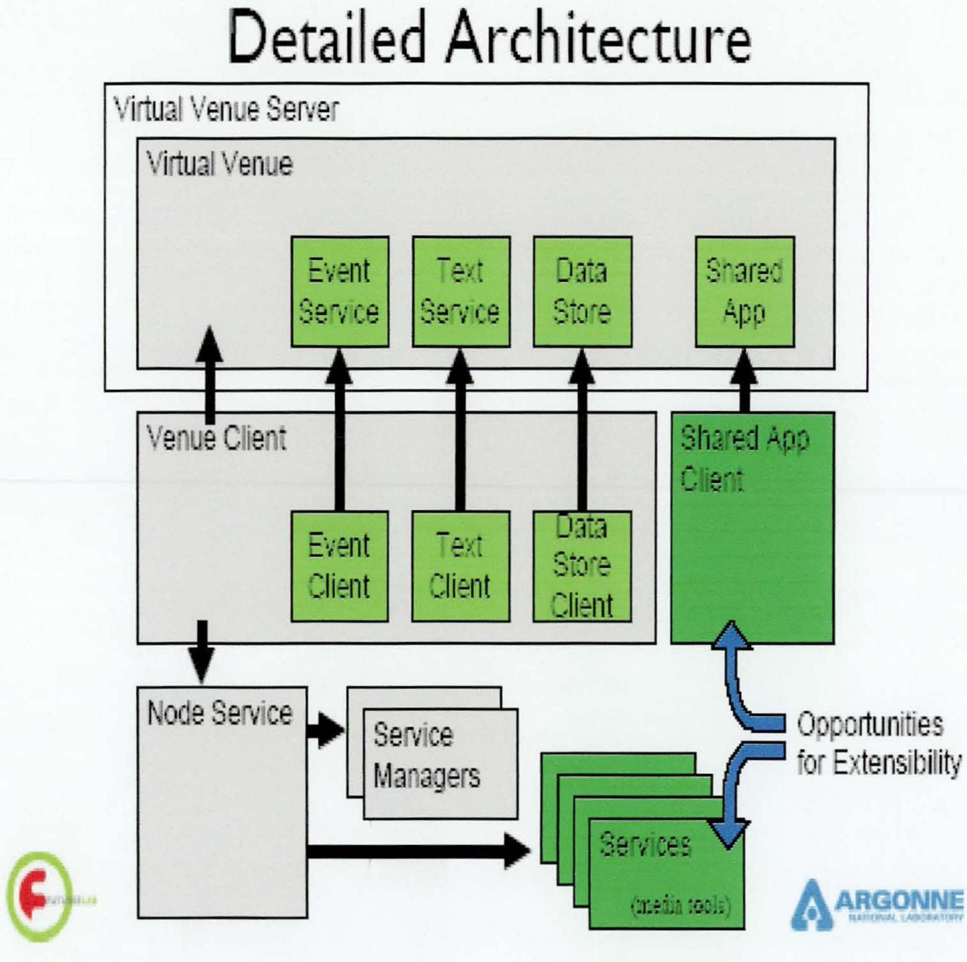


Figure 6.8: The Access Grid Architecture (source: Uram, 2006)

The AG has issued over 3,400 certificates to users across 47 countries. Each institution has one or more AG nodes, or "designed spaces," that contain the high-end audio and visual technology needed to provide a high-quality compelling user experience. The nodes are also used as a research environment for the development of distributed data and visualisation corridors and for the study of issues relating to collaborative work in distributed environments.

The AG technology was developed by the Futures Laboratory at Argonne National Laboratory and is deployed by the NCSA PACI Alliance. The Futures Lab continues to conduct research into ways to improve the AG, for example, to increase the scalability and to enhance the user interfaces (AccessGrid, 2005).

- **The BioGRID**

The BioGRID is a developed access portal for bio-molecular modelling resources. The project was led by Warsaw University, under the guidelines of EUROGRID. Different interfaces were developed to enable chemists and biologists to submit their work to available facilities. The main task of BioGRID is to integrate some of the selected applications into the UNICORE-based infrastructure and to provide relevant tools to non-experts in high performance computing (HPC). Toolsets and user interfaces for both simulation and visualisation of bio-molecules were developed.

Interfaces to the various databases, usually accessible over the Internet and from all over the world have been provided to the users. This allows simplification of access to databases and integration of them with simulations. The 'BioGRID was available to the users first at the EUROGRID partner institutions and then for the general bio-molecular community as soon as the required interfaces were developed' (EUROGRID, 2005).

Figure 6.9 represents the BioGrid architecture.

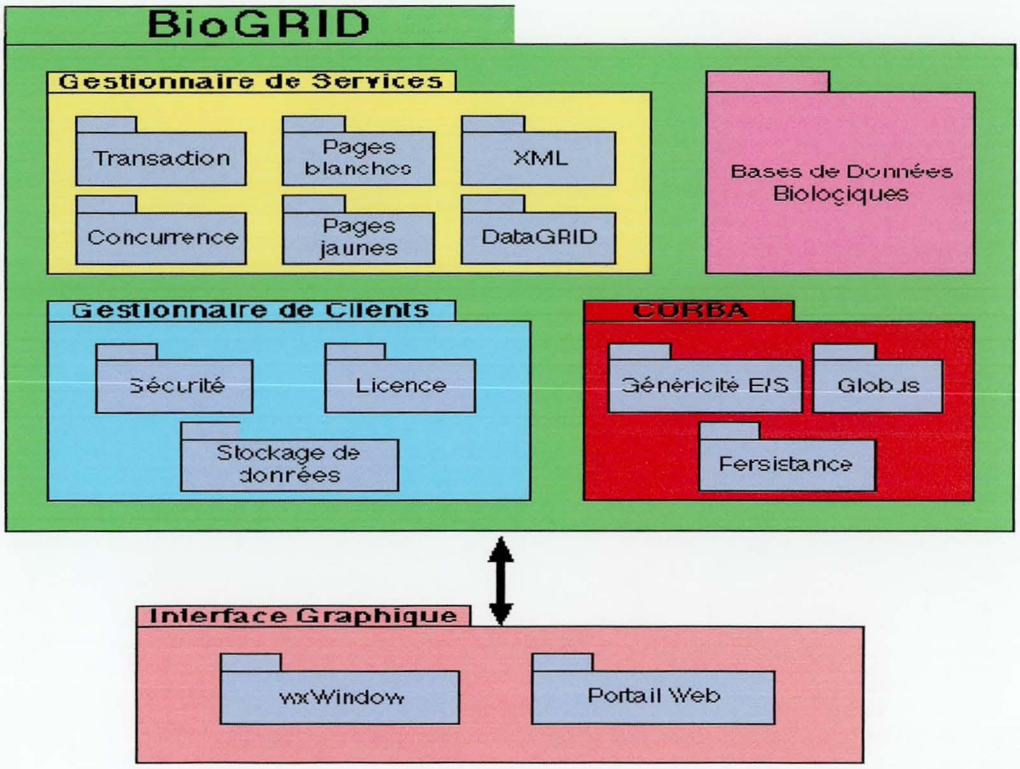


Figure 6.9: The BioGrid Architecture (source: PCSV, 2006)

- **The INFNGrid**

The INFNGrid project was started in 1999 in order to develop the first Italian Grid, based on the Italian research network (GARR). This is now well-integrated with various Grid infrastructures all over the world. The INFNGrid counts more than 20 sites amongst the most important Italian universities and, although primarily focused on the development of computing infrastructures for physics, it has been opened up to other fields of research, such as bio-medicine and earth observation, as well as to industry.

Furthermore, in 2001 INFN in collaboration with CERN and various European industries launched the largest FP5 European Grid project, the DataGrid, which is a milestone towards an infrastructure that aims to support the common European Research Area. With the CERN coordination and the collaboration of other institutes from almost all European countries, INFN has promoted the new EGEE (Enabling Grids for E-science in Europe) FP6 project, which started on April 1st 2004. The primary goal of this project is to create a seamless European Grid infrastructure for the support of the European Research Area. Information provided in this Sub-section is mainly extracted by the Grid.infn (2005) Web site.

- **NEESGrid**

The Network for Earthquake Engineering Simulation project called NEESGrid, 'is dedicated to the grand challenge of preventing earthquake disasters' (Kesselman et al, 2004). NEES is a virtual collaboration that links researchers at some 20 geographically distributed equipment sites through high-speed Internet connections. 'Sharing computer simulation software, high-performance computing clusters, and research data stored in online repositories, the NEESGrid takes advantage of the Grid tools and technologies developed over the years' (The Globus Alliance, 2006). In particular, researchers and students are able to operate equipment and observe experiments from anywhere on the Internet. They have access to 'a bank of earthquake engineering data and to high performance computational tools for analysis, simulation, visualisation and modelling' (Bemet, 2006). The NEESGrid architecture is presented in Figure 6.10.

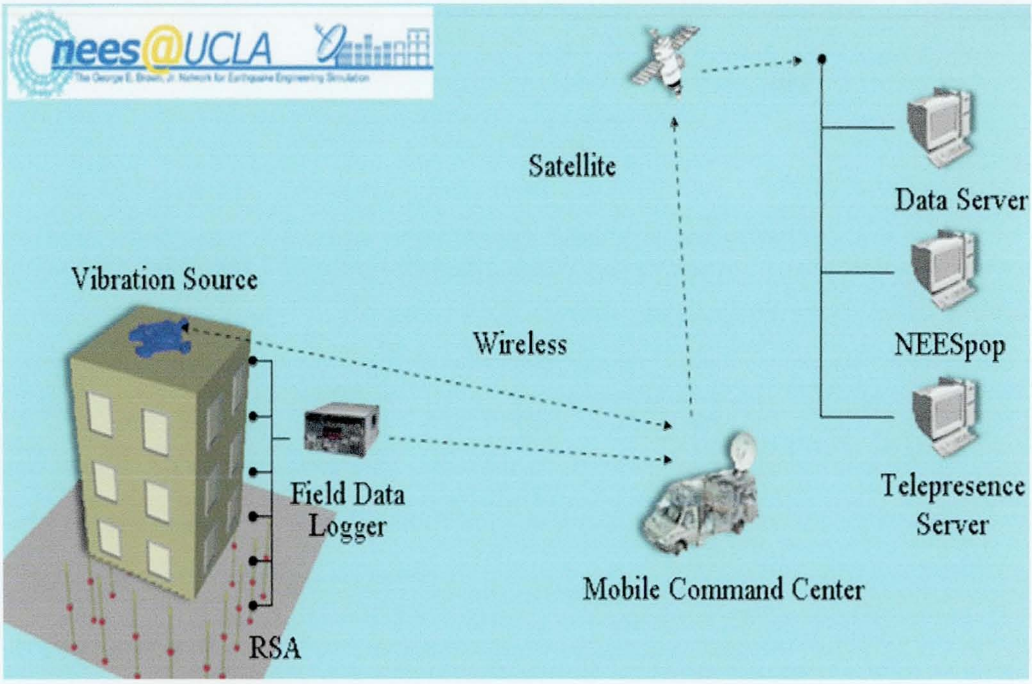


Figure 6.10: The NEESGrid Architecture (source: NEESGrid, 2006)

- **Grid-enabled Product Supplier Catalogue Database (PSCD)**

This collaborative project is held between the Engineering and Computing Departments of Cardiff University. It is possibly the first Grid application in the Architecture, Engineering and Construction industry. The project acknowledges that there is a need for consortia consisting of companies and individuals, who work collaboratively throughout the duration of a large project. 'Such projects are complex and the consortia members provide a range of skills to the project from its inception to completion. The planning, implementation and running of these A/E/C industry projects require the formation of secure virtual organisations (VOs) to enable collaboration between their members by sharing project information and resources. An important feature of the consortia is that they are dynamic in nature and they are formed for the lifetime of the project. Members can participate in several consortia at the same time and can join or leave a consortium as the project evolves' (Joita et al, 2006). In particular, the Grid-enabled Product Supplier Catalogue Database (PSCD) application, aimed to bring together designers, contractors, suppliers and product manufacturers to work collaboratively in multiple consortia in a virtual environment. Figure 6.11 gives a conceptual view of the PSCD application and its collaborative aspects using the Grid infrastructure.

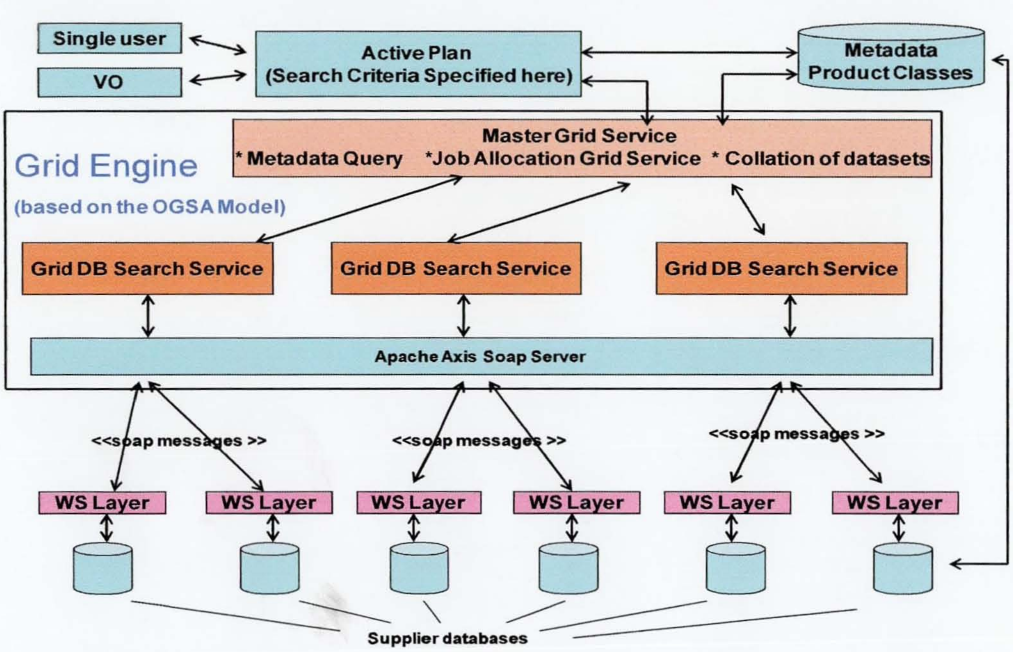


Figure 6.11: Grid-enabled Product Supplier Catalogue Architecture (source: Burnap, 2006)

6.7 The Potential Use of Grid Technology in Emergency Response Management

The primary aim of this section is to explore whether Grid technology could be used to improve the management of response operations in emergency situations caused by natural disasters in a more effective and efficient way. To achieve this, the requirements drawn from the literature review and from the interviews with emergency management stakeholders are reviewed. After this, the possibilities in using Grid technology as a collaborative ICT to address current ICT limitations within the area are presented. The outcomes of the structured interviews with experts from the field of Grid computing are also presented. The integration of these findings are then used to discuss whether Grid technology can serve as an infrastructure to overcome the incompatibility and other problems associated with current ICT usage during emergency response operations.

6.7.1 Emergency Response Management Stakeholders' Requirements

The findings from previous chapters identify that 'natural phenomena are unavoidable and necessary planetary actions, which may cause disastrous results to the human environment if they occur in extreme forms' (Asimakopoulou et al, 2004; 2005). In turn, the emergency management discipline has been formed to organise, analyse, plan, make decisions, and finally assign available resources to mitigate, prepare for, respond to, and recover from all effects of all disasters (Nalls, 2003; Trim, 2003; Shaw et al, 2004). In managing a disaster, it is apparent that a number of teams and individuals from multiple, geographically distributed organisations will be required to communicate, co-operate and collaborate in order to take appropriate decisions and actions (Graves, 2004; Otten et al, 2004). 'The need for information exchange during an emergency situation is present; however it can be very diverse and complex' (Carle et al, 2004). Carle et al (2004) also report that 'there are frequent quotes regarding the lack and inconsistent views of information shared in emergency operations'. There are many small communities that 'do not have the resources, personnel and expertise to develop a set of requirements to assist them in managing their activities as they pertain to emergency response' (Bui and Lee, 1999). Moreover, recent emergency management approaches are also characterised as inefficient because of their 'unstructured poor resource management and centralised nature with fixed hierarchical instructions' (Scalem et al, 2005). Many scholars in the field also point out that for the management of emergency response operations, a number of ICT and relevant collaborative computer-based systems have been developed to assist the requirements of many segmented organisations to bring together their intellectual resources and the sharing of accurate information in a timely manner (Howard et al, 2002; Graves, 2004). However, findings as presented by an NRS report (2006) suggest that sustained efforts should be made with respect to data and resource archiving, sharing and dissemination. NRS (2006) refers to it as the 'hazards and disaster research informatics problem' that is not unique to this research specialty, or other fields but it demands immediate attention and resolution'. These findings are also supported from the primary research findings since all emergency management interviewees highlighted the inefficiency of their ICT infrastructure. Such ICT infrastructure includes but is not limited to databases, Geographical Information Systems (GIS), mobile phones, landlines, VHF Radios, portable devices, weather station instruments, geological instruments, satellites, sensors and simulation tools. Underlying technologies to support the use of current ICT as discussed in Section 6.4 include the Semantic Web, Intelligent Agents, Decision Support Systems, Wireless Communication and Advanced Visualisation Systems. Furthermore, stakeholders characterised the gathering of required meetings as time-consuming. They also pointed out that moving from one place to another limits them in access to their data. Other problems reported include the incompatibility between ICT equipment used, which results from stakeholders using different types of equipment, which in turn may contribute to transfer delays and loss of accurate information.

Additionally, there is a requirement for portable, take-over resources to respond to situations where centralised resources fail. Another important constraint is that emergency teams operate under stress (Staw et al, 1981; Rice, 1990) in a distributed environment whilst 'they are required to maintain high standards of control in order to take appropriate decisions and actions' (Carle et al, 2004). They have to make decisions based on what is known within a certain timeframe. Hence, knowing what distributed resource is available at any given time is critical for taking an informed and distributed decision. In particular, stakeholders identified the ICT related limitations given in Table 6.1:

Table 6.1: Current ICT Limitations during the Emergency Response Operations (previously presented on Table 4.1)

Current ICT Limitations during Emergency Response Operations
▪ *Gathering of stakeholders to a centralised place is time consuming;*
▪ *Centralised store of important information;*
▪ *Gathering of stakeholders to a centralised place limits access to individuals' centralised resources/data;*
▪ *Non-timely exact information about the phenomenon;*
▪ *Not exact information about available resources;*
▪ *No real-time pictures;*
▪ *Failing of telephone networks;* ▪ *Overloaded telephone networks;* ▪ *Possible computer network failure;*
▪ *Incompatibility of computerised means of communication.*

Integration of these with other findings using the SSM epistemology led to the identification of a conceptual Emergency Response Model (ERM) for natural disasters as described in Sub-section 5.3.1.1. Findings as analysed in Section 5.3.1 clearly show that there is a need for a computerised method that will allow emergency management decision makers to make more informed decisions via the incorporation of the minimum activities of the proposed ERM in a dynamic fashion. That is to say, the adopted ICT method should allow the following set of requirements including the ability for:

Table 6.2: The Set of Requirements for the ERM (as seen originally in Table 5.1)

SET OF REQUIREMENTS for the ERM
1. Emergency management authorities stakeholders to work remotely and

	collaboratively in order to plan, control, coordinate and communicate relevant actions in a more effective and efficient way;
2.	Stakeholders to dynamically receive the most up-to-date information of what is the current situation (upon request);
3.	Stakeholders to dynamically receive the most up-to-date information in relation to what resource is available to use (upon request);
4.	Stakeholders to work in an environment that is free of any ICT compatibility problems;
5.	ICT resources to dynamically collect, store the most up-to-date information of what is the current situation;
6.	ICT resources to dynamically assess and allocate incomplete jobs to other available resources if they become unavailable;
7.	ICT resources to interoperate in a compatible way;
8.	All resources to dynamically and collaboratively work in an environment as defined by the set of policies.

To this end, stakeholders have made it clear that there is no particular concern with individual ICT, however, they are clearly dissatisfied with the collaborative nature of these distinct ICT. Current ICT in use are mostly limited by simply behaving as loosely coupled technologies.

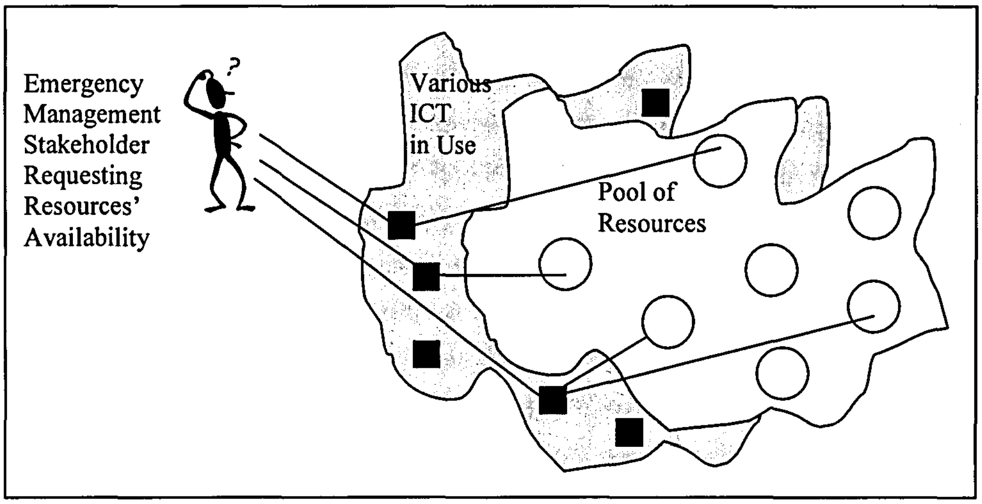


Figure 6.12: Emergency Management Stakeholders Requesting Resource Availability

That is to say, emergency management stakeholders are required to identify resource availability from a pool of resources by repeatedly requesting availability for each resource every time it is required via the use of various ICT. The situation is illustrated in Figure 6.12.

6.7.2 The Potential Use of Grid Technology as a Collaborative ICT

In tackling these generic types of ICT related constraints, the concept of Grid emerged. In fact, the notion of Grid technology has emerged as a thoroughly viable method to support the coordination of electronically and dynamically available shared resources over a distributed heterogeneous environment to assist distributed and heterogeneous virtual teams to solve a common problem. It is believed that Grid technology should be considered the appropriate technology to support decision makers and operational units during the response phase to an emergency situation caused by the occurrence of a natural catastrophic event.

Foster et al (2001) and Newhouse (2002) said that the ultimate vision of the Grid is to provide a ubiquitous infrastructure that allows flexible, secure, co-ordinated on-demand resource sharing among dynamic collections of individuals, institutions and resources). Similarly, 'managing an emergency situation may require the seamless access and use of human and computer-based distributed resources' (Geddes, 2003), as it may support the creation of 'an open database that gives each team member direct access to important information' (Gould and Joyce, 2003). Fox et al (2006) stated that disasters 'require the quick deployment of a new VO consisting of diverse, pre-existing Grid components'.

The deployment of a Grid infrastructure on top of the existing resources that relief bodies currently have could assist in solving ICT related incompatibility problems. This is due to the fact that Grid technology emerged as the computer-based method to allow multiple distributed owners to form a VO via sharing, integrating and virtualising their numerous heterogeneous resources and expertise in a dynamic fashion that are governed by differing policies.

6.7.3 Evaluation of the Possibilities in Using Grid Technology in Emergency Response Management

One-to-one structured interviews were conducted with six experts in the area of Grid technology with the aim of discussing and evaluating the opportunities in using Grid technology within emergency response management. This was intended to inform the development of an appropriate conceptual Grid-Aware Emergency Response Model based on the SSM model defined in Chapter 5. These interviewees were all highly research active in the area of Grid technology:

- The Deputy Director of Chimera, University of Essex;
- The Principal Researcher of Chimera, University of Essex;
- A Senior Lecturer, Institute for Research in Applicable Computing, University of Bedfordshire;
- The Director of the Research School of Systems Engineering, Loughborough University;
- An Associate Researcher, Condor Project, University of Wisconsin-Madison (USA);
- The Director of Community Grid Laboratory, Director of Pervasive Technology Laboratories, Indiana University (USA).

A description of the processes related to the emergency response operations and their associated ICT limitations in the form of a Rich Picture and a text-based case scenario describing concerns presented in Tables 6.1 and 6.2 were given and explained to the subjects. On this basis, the need for each one of the bodies involved to coordinate its resources effectively, but most importantly the need for communication and collaboration between these bodies – by utilising their different systems in a holistic way and provide effective, efficient and holistic coordination of the complete set of the available resources – was stressed to the interviewees. Finally, it was also made clear to the interviewees that the focus of the study is to investigate if Grid technology could utilise existing and emerging technologies towards the filling of the technological gap and to propose an improved solution for the collaboration, communication, coordination, control and allocation of available resources during the response phase to a natural disaster. A dictation machine recorded interviewees' oral responses to the structured questions provided. The term "structured interviews" refers to those interviews which 'are rigidly standardised and formal, that is the same questions presented in the same manner and order' (van Dallen, 1979). These questions were as follows:

- Grid technology facilitate parallel problem solving capabilities for single and/or aggregated computations. To what extent could Grid technology facilitate a more effective and efficient collaboration, decision-making and coordination of distributed resources within an emergency response operation?
- Currently a system breakdown or failure results in a delay or non-completion of an assigned task. Could a Grid-enabled system overcome these problems, how and to what extent?
- Could other technologies used by relief organisations, such as GIS, VHF radio, satellite audiovisual equipment, text messaging and wireless communication devices be integrated and co-work (not only co-exist but work together) in a Grid infrastructure?
- What are the main technologies, architectures (technical aspects) that should be considered as necessary to support the creation of a Grid middleware to integrate existing resources?
- What are the protocols and languages required for such a development?
- Are there any particular requirements for hardware – currently used by organisations – to join the integration? What else is required?
- Can you explain the most important concerns, limitations or disadvantages with Grid technology (security, ownership, resource discovery, allocation and management). To what extent, could these affect the operational order of the proposed Grid-based emergency response system?
- Can you see any emerging technologies that could strength and extend or even replace the Grid concept and its real-world application in the next decade?

Free written transcriptions were made of the oral discussion and these are documented in Appendix III. The following paragraphs highlight the major issues with respect to each question:

- **Grid technology facilitate parallel problem solving capabilities for single and/or aggregated computations. To what extent could Grid technology facilitate a more effective and efficient collaboration, decision-making and coordination of distributed resources within an emergency response operation?**

Five out of six experts agreed that Grid technology could serve this area as it provides support for collaborative, distributed working. In particular, three subjects agreed that this is an interesting project and that Grid technology will particularly benefit the decision-making process by accommodating dynamic collaboration between virtual organisations. The sixth participant felt that Grid technology would not be able to serve in this area. This is because there are many things to be done in individual areas, for example, there is a need for authorities in the area to computerise their resources first. Overall, all experts felt that emergency management has many problems with the supportive ICT at the moment, whilst most subjects felt that if all the authorities involved were working towards sharing their resources through a Grid environment, this would lead to more effective and efficient emergency response management in terms of collaboration, coordination, planning and decision making. Finally, one participant from the US noted that he is currently involved with projects focusing on improvements in this area.

- **Currently a system breakdown or failure results in a delay or non-completion of an assigned task. Could a Grid-enabled system overcome these problems, how and to what extent?**

One of six participants felt that a Grid-enabled system could overcome such problems to an extended degree. A similar but much stronger view was expressed by the remaining five experts, who agreed that Grid environments have the advantage to overcome such problems, as they are own managed and they can assign jobs accordingly. These participants felt that a Grid system could overcome these problems by assigning the task to another available resource with the same expertise without losing any vital time. In particular, one of the participants explained that a Grid-enabled system would be able to overcome such failures using its embedded fault tolerance capability. This means that when a node is not working for any reason, the system finds the next available one and assigns the job to it.

- **Could other technologies used by relief organisations, such as GIS, VHF radio, satellite audiovisual equipment, text messaging and wireless communication devices be integrated and co-work (not only co-exist but work together) in a Grid infrastructure?**

All six experts agreed that Grid technology have the capabilities to achieve this; however, they also agreed that there is the need for research and improvement in the other technologies and equipment and at the same time there is the need for a relevant middleware to support the co-working of all these systems. Clearly, the latter point supports the underpinnings of this research namely to develop a Grid-Aware Emergency Response Model, as it needs to be produced prior to the development of a particular middleware.

- **What are the main technologies, architectures (technical aspects) that should be considered as necessary to support the creation of a Grid middleware to integrate existing resources?**

Five out of the six participants agreed that the primary architecture should be OGSA whilst the remaining subject felt that this depended on the existing resources. These five experts felt that an open operating systems architecture like UNIX/Linux would be advantageous but the latest developments in OGSA and OGSI suggest the feasibility over Windows-based operating systems. Three participants suggested that the main technologies to be considered include Web Services and OGSA-DAI as the service-oriented approaches to bridge communication across different services, such as databases, data mining, software, applications, nodes and instrumentation.

- **What are the protocols and languages required for such a development?**

All six participants agreed that this depends on the existing infrastructure and the choice of the Grid toolkit or server environment to support the development of the application. However, they all agreed that there is a wide range of choices to select from. Currently, programming languages used include C, C++, XML, Perl and Java.

- **Are there any particular requirements for hardware – currently used by organisations – to join the integration? What else is required?**

All six experts agreed that this depends on the equipment the organisations involved currently own. They also agreed that there is no need for any sophisticated hardware to create the middleware. However, one expert felt that there will be a need for some new hardware – such as servers, computers etc. – in order to create the Grid environment.

- **Can you explain the most important concerns, limitations or disadvantages with Grid technology (security, ownership, resource discovery, allocation and management). To what extent, could these affect the operational order of the proposed Grid-based emergency response system?**

Five out of the six experts agreed that the real concern lies with the authorities involved in emergency management, as they will be required to adopt a new way of operating. One of these five participants, along with the sixth felt that the challenge would be the need for the creation of electronic forms of any manual system that exists in the organisations involved. However, four out of the five experts felt that the most important challenge is that of training all the people involved. All six agreed that users will have to learn to operate the system productively under stress, and as they will not be able to use it in everyday life, preparedness exercises may be required. Finally, one of the five experts felt that the real challenge would be the cost of this integration. He stated that currently the US Government spends considerable sums of money on the development of such systems for military purposes.

- **Can you see any emerging technologies that could strengthen and extend or even replace the Grid concept and its real-world application in the next decade?**

All six experts agreed that this was a difficult question to answer. They all see Grid technology as having a long future. Three participants expressed the view that Grid technology is the first technology that is able to overcome incompatibility problems of current ICT and is also the first technology that facilitates resource sharing and high-speed problem solving. The remaining three experts did not discount these but felt that Grid technology will last for many years and the main challenge will be the integration of other technologies with them. Finally, one expert felt that the fine-tuning of collaborative multi-purpose agent technologies could be the key for enabling virtual organisations to make chain-based decisions in a dynamically changing environment.

Overall, the structured interviews indicated that the five out of the six participants felt that it is possible and useful to employ Grid technology within the emergency response management. The remaining expert claimed that it is not feasible due to the need for digitising manual systems first prior to their integration. However, it is important to note that the aim of this research is not to physically produce and test such a system but to investigate opportunities in using Grid technology to overcome incompatibility problems related to the ICT currently used during emergency response operations and ultimately produce the conceptual basis for such a real-world approach.

6.7.4 Identification of Whether Grid Technology could be Used in Emergency Response Operations

The findings presented in the previous sections support the concept that Grid technology can be used during emergency response operations. They will offer stakeholders with numerous of opportunities in response to the limitations as presented in Table 6.1. In particular, it has been found that the limitations of current ICT in use during emergency response management (Table 6.1) adversely affect the effective and efficient accomplishment of tasks in relation to the set of requirements identified by emergency management stakeholders (Table 6.2). However, the literature review presented in this Chapter, as well as the views expressed by Grid technology experts indicate that there are a number of Grid related methods, which potentially could be employed to assist in addressing the limitations of current ICT in use. These would enable more effective and efficient accomplishment of tasks in relation to the identified set of requirements. These views are illustrated in Figure 6.13.

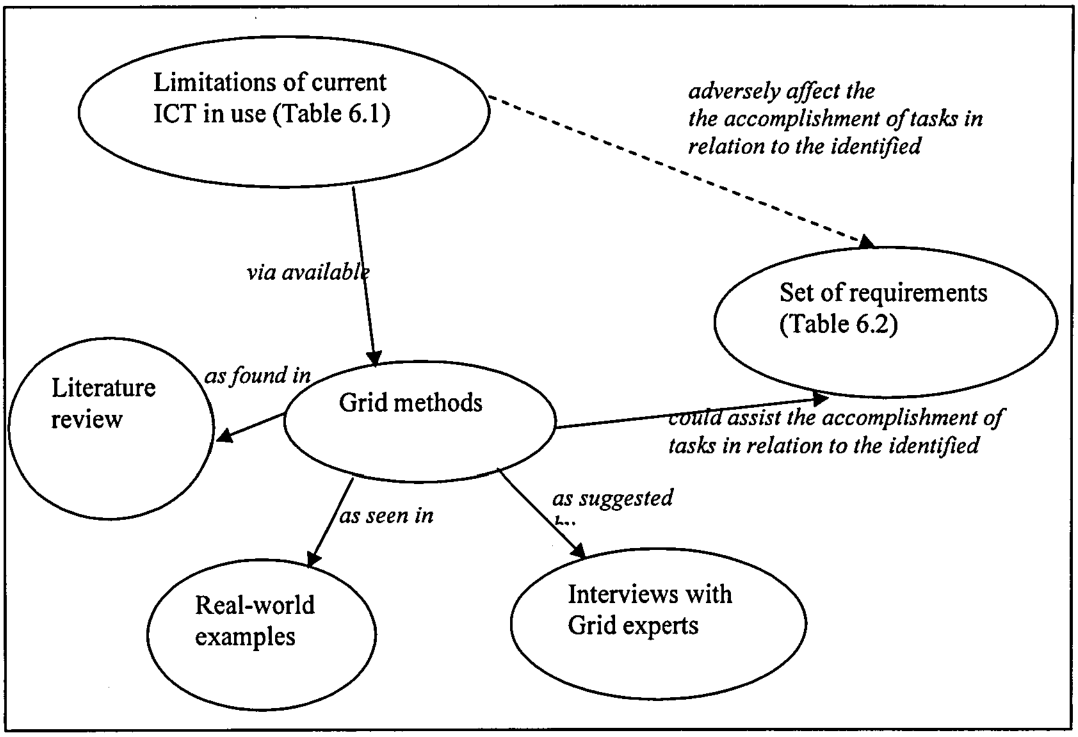


Figure 6.13: Alleviating Current ICT Limitations Using the Grid

Integration of the findings summarised in Table 6.3 allowed the demonstration of how each limitation of current ICT in use during an emergency response operation can be overcome via the use of appropriate Grid methods to assist the accomplishment of tasks in relation to the identified set of requirements. Specifically, primary and secondary findings suggest that "videoconferencing" could be used to address the ICT limitation of the gathering of stakeholders to a centralised place that is considered as time consuming. Similarly, findings as described earlier suggest the use of "Data and Quality of Service register mechanisms via the methods of OGSA-

DAI, Web Services and the Semantic Web" and "remote resource management via Web Services" could assist in overcoming the ICT limitations of the gathering of stakeholders to a centralised place that evidently limits access to individuals' centralised resources/data and the ability to manage centralised stores of important information.

On the same basis, "Data discovery mechanisms via the use of OGSA-DAI, Web Services, Semantic Web and Decision Support Systems", "Mechanisms that can intelligently and transparently identify, select and allocate computer-based resources capable of running user's request; via the use of Intelligent Agents and Job Schedulers", as well as "Integration and virtualisation of multiple distributed, heterogeneous, and independently managed instrumentation based sources via OGSI, OGSA-DAI and Advanced Visualisation Systems" could be employed to assist emergency response stakeholders receiving timely and exact information about resource availability, the phenomenon it self and access to real-time information, including real time images.

Moreover, ICT limitations related to failures of computer networks or failures of telephone networks caused from overloads or other physical reasons could be overcome by using "wireless communications", "Backup/restore mechanisms and policies necessary to prevent data loss and minimise unplanned downtime across the Grid" or via embedded "Failure detection and fail-over mechanisms" which would allow "Dynamic job re-scheduling, re-routing and re-allocation once resource becomes unavailable". This can be achieved via the OGSA/OGSI Fault Tolerance services. Finally, "Integration and virtualisation of multiple distributed, heterogeneous, and independently managed data, resource and instrumentation based sources via OGSI and OGSA-DAI" could be utilised to address various ICT incompatibility issues.

Table 6.3: Overcoming Current ICT Limitations Using Grid to Assist the Defined Set of Requirements

SET OF REQUIREMENTS for an Emergency Response Model							
1. Emergency management authorities stakeholders to work remotely and collaboratively in order to plan, control, coordinate and communicate relevant actions in a more effective and efficient way;	2. Stakeholders to dynamically receive the most up-to-date information of what is the current situation (upon request);	3. Stakeholders to dynamically receive the most up-to-date information in relation to what resource is available to use (upon request);	4. Stakeholders to work in an environment that is free of any ICT compatibility problems;	5. ICT resources to dynamically collect, store the most up-to-date information of what is the current situation;	6. ICT resources to dynamically assess and allocate incomplete jobs to other available resources if they become unavailable;	7. ICT resources to interoperate in a compatible way;	8. All resources to dynamically and collaboratively work in an environment as defined by the set of policies.

Limitations of current ICT in Use	GRID Methods
Gathering of stakeholders to a centralised place is time consuming;	Distributed virtual meetings; (Video-conferencing)
Gathering of stakeholders to a centralised place limits access to individuals centralised resources/data;	Data and Quality of Service register mechanisms (OGSA-DAI, Web Services, Semantic Web)
Centralised store of important information;	Remote manage to distributed computing resources owned; (Web Services)
Not timely exact information about the phenomenon;	Data discovery mechanisms (OGSA-DAI, Web Services, Semantic Web, Decision Support Systems)
Not exact information of available resources;	Mechanisms that can intelligently and transparently identify, select and allocate computer-based resources capable of running a user's request; (Intelligent Agents, Job Schedulers)
No real time images;	Integration and virtualisation of multiple distributed, heterogeneous, and independently managed instrumentation based sources; (OGSI, OGSA-DAI, Advanced Visualisation Systems)
Failing of telephone networks; Overloaded telephone networks; Possible computer network failure;	Use of Wireless Communications; Backup/restore mechanisms and policies necessary to prevent data loss and minimise unplanned downtime across the grid; Failure detection and fail-over mechanisms; and Dynamic job re-scheduling, re-routing and re-allocation once resource becomes unavailable; (OGSA/OGSI Fault Tolerance)
Incompatibility of the computerised means of communication;	Integration and virtualisation of multiple distributed, heterogeneous, and independently managed data, resource and instrumentation based sources; (OGSI, OGSA-DAI)

However, one of the most important opportunities in using Grid technology within the response phase of an emergency situation caused by a natural disaster is the applicability of Simon's (1977) "bounded rationality" theory that was described in Chapters 3 and 5. As Simon pointed out, a problem space represents the boundary of an identified problem and contains all possible solutions to that problem. By default, a decision maker will have to make a decision on what is known about the current situation. It is therefore expected that the deployment of Grid technology will enlarge the actual search space boundaries within the problem space. This is because Grid technology will allow emergency response management stakeholders to identify and select choices from a far larger range of resources that are available through a pool of registered resources.

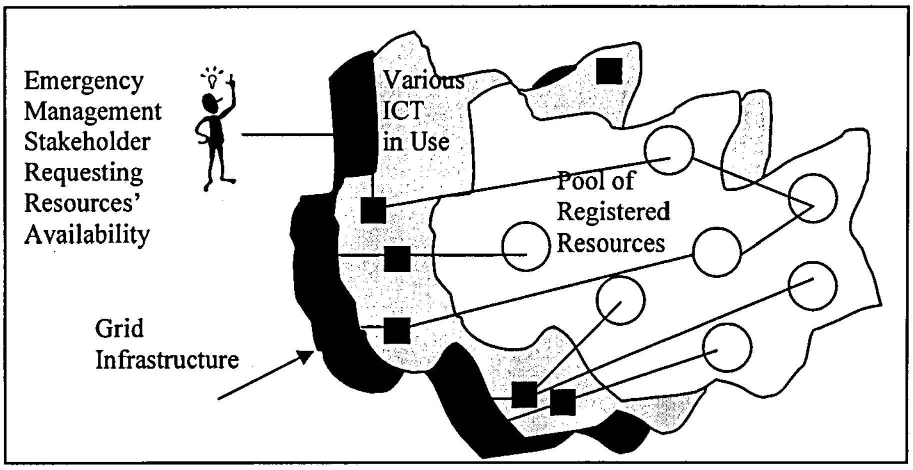


Figure 6.14: Emergency Management Stakeholders Requesting Resource Availability via a Grid Infrastructure

Hence, the larger the actual search space, the more likely the increase in the opportunities for a better solution to be encountered by a decision maker. The deployment of Grid technology will facilitate seamless access to what is possibly known and available in a distributed environment in a given timeframe, which in turn will enlarge the search space boundary. Overall, it is believed that the deployment will facilitate methods towards normative thinking as required for better decision-making in a timely fashion.

6.8 Summary

This chapter has reviewed Grid technology and their evolving standards as the latest advance to support collaboration in a distributed environment. Relevant discussion drawn from interviews with Grid technology experts and findings from primary and secondary research works concluded that it is possible and useful to deploy Grid technology as a means of improving the management of response operations in emergency situations caused by natural disasters.

The proposed approach is further developed in Chapter 7 with the aim of enriching findings towards the further development of the conceptual Emergency Response Model (ERM) resulting from the Soft Systems Methodology enquiry with Grid technology to propose a Grid-Aware Emergency Response Model (G-AERM) for managing natural disasters. The proposed G-AERM aims to serve as the framework for the development of real-world applications, as a method to support emergency response stakeholders to work remotely and collaboratively in order to plan, control, coordinate and communicate relevant actions in a more effective and efficient way.

Chapter 7 The Grid-Aware Emergency Response Model (G-AERM) for Natural Disasters

7.1 Introduction

This Chapter is concerned with the integration of the SSM-based ERM with Grid technology, as a basis of improving the management of response operations in emergency situations caused by natural disasters. It focuses on the production of relevant technical requirements based on Grid technology and thereafter with the description of a new Grid-Aware Emergency Response Model (G-AERM) for natural disasters. Illustrations of the model's architecture are used to demonstrate the various stakeholders' viewpoints and the model's supporting functions and activities. The chapter concludes with an illustration of the technical considerations for each activity of the proposed model.

7.2 Managing the Emergency Response Phase for Natural Disasters

The findings from previous chapters have led to the need for incorporating the SSM-based Emergency Response Model (ERM) developed earlier with Grid technology. Section 4.7 indicated that the area of emergency response management is characterised by distributed operations that are of a multidisciplinary and interdisciplinary nature. Emergency management authorities are required to cooperate in order to plan, control, coordinate and take appropriate decisions and provide with an effective and efficient response to an emergency situation caused by the occurrence of a natural disaster. On this basis, a number of processes – distributed in nature – take place during the emergency response phase, as these have been identified by emergency management stakeholders.

To achieve the effective and efficient management of the emergency response operations, a number of resources owned by each emergency management authority are made available for disposition. Resources – like their owners – may be distributed and/or multidisciplinary in nature. It is important to recall that disposal and use of resources, as well as all decisions made must be in-line with a number of policies including the bodies of law, as they are predefined by the emergency plans.

Findings drawn from the one-to-one structured interviews with emergency management stakeholders demonstrated that during the emergency response operations, information management becomes absolutely crucial. Emergency management stakeholders – as decision makers – require continuous access to various distributed resources in order to plan and make appropriate decisions, as well as to allocate resources for a particular task. Integration of these findings led to the production of a set of requirements for emergency management stakeholders to respond appropriately in an emergency situation, as seen in Table 5.2.

Regarding the management of a situation in general, Section 3.7 described Simon's "bounded rationality" theory. In particular, the theory suggests that despite the attractiveness of identifying the best possible solution as a decision-making strategy, its practical application is problematic. This is due to the fact that reality is too large to be handled and, therefore, it may not be feasible to know what is required at a given timeframe. Even if it was virtually known of what is required, decision makers may not have access to it at all or at the right time. Although supporting ICT and relevant collaborative computer-based systems that have been developed would be adequate to support the requirements, findings drawn from primary and secondary research support the recommendation made by NRS (2006), which refers to the 'hazards and disaster research informatics problem'.

Various limitations of ICT were confirmed with emergency management stakeholders who stressed the need for bringing together all their resources in a collaborative and timely manner. Stakeholders have made it clear that there is not any particular concern with individual ICT; however they are clearly dissatisfied with the collaborative nature of these distinct ICT. They identified a number of limitations associated with ICT in use during emergency response operations, as presented in Chapter 4.

Analysis of the findings using the SSM approach led to the identification and organisation of the minimum activities required to take place in order to manage the emergency response operations in Greece and England. In turn, a conceptual

Emergency Response Model (ERM) illustrating the dependencies between the minimum activities required to respond in emergency situations caused by natural disasters has been produced. It is important to stress that the development of the SSM-based conceptual ERM appreciates limitations of current ICT in use during emergency response operations. However, the primary aim of the ERM was to identify the specific minimum activities required to take place in order to manage the emergency response operation. That is to say, the proposed ERM is medium-free and, as findings indicated in Section 5.3.1, there is a need for a computerised method that will allow emergency management decision makers to make more informed decisions via the incorporation of the minimum activities of the proposed ERM in a collaborative and dynamic fashion. To this end, further analysis of ICT limitations led to the recognition that Grid technology – as a cutting edge collaborative ICT – could pair with the aforementioned SSM based conceptual ERM. These are fully described in Chapter 6 and briefly presented next.

Research findings, as noted in Sections 4.10 and 4.11, indicated that a range of ICT is used in order to assess the disaster situation and to respond to it. It is important to note that these ICT are distributed in nature and owned by different dispersed organisations. These ICT instruments include computers, landlines, mobile phones, networks, mobile units, VHF radios, PDA, pagers, messengers, satellites, earth observation or other detection systems, geographical information systems, global positioning systems, databases, satellite phones, seismographs and in general every other instrument the emergency management stakeholders believe it is essential in order to carry out an effective and efficient response operation. However, research findings, as highlighted in Section 4.11, indicated that there are a number of weaknesses with the current ICT used in emergency response operations. These are noted in Table 4.1.

Amongst other things, stakeholders have pointed out that it is inefficient for them to leave their bases in order to meet at the office of the operation's leader in order to manage the situation in a collaborative way. They found the method time-consuming, whilst the incompatibility of their ICT limits them in having access to their own data stores and in communicating directly with their operational units or their other resources. Incompatibilities between ICT also have caused communication of inaccurate information between senders and receivers or even delays in communicating decisions, plans of action or information collected from various senders to other relevant receivers. Overall, ICT incompatibilities have caused lack of the right information in time, which in turn may result in not taking into consideration a resource that is available but not known to relevant decision makers. Moreover, it has been found that there are situations where a computational resource is required to run complex what-if scenarios and simulations in order to assist decision makers in taking a more informed decision. These clearly demonstrate an incomplete collaborative approach.

Literature-based findings indicated that the latest developments in relation to networking and resource integration have resulted in the concept of Grid technology. This refers to an infrastructure and set of protocols to enable the integrated and collaborative use of distributed heterogeneous resources including high-end computers, networks, databases, and scientific instruments owned and managed by multiple organisations, referred to as Virtual Organisations (VO). Resources cover a wide range of concepts including computation, communication, storage, databases, archives, instruments, people and the expertise they represent, software packages, brokering and scheduling services and frameworks for access and control of these resources. An important aspect of Grid technology lies in the ability to allocate and re-schedule resources dynamically in real-time according to the availability or non-availability of optimal solution paths and computational resources.

Secondary research findings in relation to cutting-edge collaborative ICT have been paired with primary research findings drawn from one-to-one structured interviews with six experts in the area of Grid technology aiming to discuss and evaluate the opportunities in using Grid within the area of emergency response management. These activities led to the suggestion that it is possible and useful to employ Grid technology within the emergency response management domain. In particular, activities related to the integration of findings led to the production of a matrix, as seen originally in Figure 6.15. The matrix demonstrated how each limitation of current ICT (as seen in Table 4.1) in use during an emergency response operation could be resolved via the use of appropriate Grid technology to assist the accomplishment of tasks in relation to the identified set of requirements, as seen in Table 5.2.

Therefore, both primary and secondary research findings have indicated that during emergency response operation stakeholders need to:

- Work in a collaborative manner to make informed decisions based on multiple dispersed resources;
- Increase their understanding about the situation by knowing as much as is possible in relation to what is distributed available at a given timeframe;
- Run complex and intensive application problem-solving scenarios in parallel.

In conclusion, the proposed approach will allow multiple distributed owners to form a VO to share, integrate and virtualise their numerous heterogeneous resources and expertise in a dynamic fashion that are governed by differing policies. It is therefore believed that the deployment of a Grid infrastructure on top of the existing resources from the authorities involved in emergency response management and other organisations could assist in tackling ICT related incompatibility problems and foster collaboration in an improved manner by utilising a multidimensional approach.

7.3 Development of the Grid-Aware Emergency Response Model (G-AERM)

This section is concerned with the development of a relevant set of technical requirements based on Grid technology as the underlying method to improve decision-making during emergency response operations. To achieve this, the following issues need to be taken into account in developing the G-AERM:

- **Linking SSM with ISDMs**

SSM conceptual (activity) models can form a cogent basis for information flow models upon which a real-world application can be based. However, there is no systematic way of determining what information is needed or produced by such an activity, or for developing data models. That is to say, there is no systematic way to connect SSM conceptual models with standard Information Systems Design Methodologies (ISDMs). However, Checkland and Scholes (1991) have pointed out that SSM subsumes the "hard" approach, which is a special case and arises when there is a local agreement on some particular systems to be engineered. On this basis, it can be argued that the SSM-based Emergency Response Model developed includes local agreements on what needs to be created in a real world system. That is to say, the SSM approach produced a conceptual model, which along with the primary research findings highlighted potential opportunities for using Grid technology in the real world.

- **Guidelines for Producing Real-World Technical Requirements**

Newman and Lamming (1995) suggest that the following four aspects of a model or system can be expanded into a set of real-world technical requirements:

- The User;
- The Activity to be Supported;
- The Usability Factors;
- The Form of the Technical Solution.

Consideration of "Usability Factors" is considered to be beyond the scope of this research, as its primary goal is not to produce a real-world application but to provide a model to serve as the underlying framework for the development of real-world applications. The other three aspects are discussed bellow:

- The User: This is concerned with the description of the expected user roles supporting emergency response operations.

- The Activity to be Supported: This is concerned with the identification of the activities to be supported in a model or system by presenting the tasks and the processes as the sequence of steps which contribute towards the overall goal of an end-user, and it is illustrated in the form of a process flow chart (Newman and Lamming, 1995). On this basis:

- o Activities (as specified in Table 5.1) which have been incorporated in the SSM based ERM alongside the set of requirements and outline Grid features (as seen in Figure 6.15) are used to produce a relevant process flow chart;
- o Incorporation of the SSM-based conceptual ERM with the produced process flow chart is used to outline the proposed G-AERM.

- The Form of the Technical Solution: This is concerned with the formation of a relevant specification framework that could be used as the basis for engineering a real-world application (Newman and Lamming, 1995). On this basis:

    - o Integration of the proposed G-AERM with the produced process flow chart and detailed Grid related findings from Chapter 6 are used to describe the set of real-world technical requirements for the G-AERM architecture.

7.3.1 The User

Emergency management stakeholders suggested the existence of two main categories of user roles namely the Resource Seeker and the Resource Provider:

- **Resource Seeker:** Resource Seeker is a user who requires resources for executing a job. For example, decision-makers are Resource Seekers when they need to know what resources are available prior to making a decision. Another example is the master computer of a cluster when it is trying to identify available nodes to undertake jobs described in the job plan. The category of the Resource Seeker may include the decision-makers and the operational units.

- **Resource Provider:** Resource Providers are all the authorities that have made their resources available during an emergency response operation. For example, the Police Department is a Resource Provider when it makes available its officers, cars or ICT in order for use in emergency response operations or when it provides their expertise to assist in decision-making. Another example of a Resource Provider is any external organisation that has made its computer equipment (hardware and/or software) available through the proposed ICT environment in order to co-execute highly demanding tasks with other available computers. The category of the Resource Provider may include the decision-makers and the operational units.

7.3.2 The Activity to be Supported / Process Flow Chart

The purpose of the process flow chart is to identify the tasks and to specify outline Grid-based processes that lead to the overall goal of emergency response management stakeholders to plan, control, collaborate, co-ordinate and communicate actions during emergency response operations. Table 5.1 lists the activities for the SSM-based ERM.

Table 7.1: The Set of Requirements for the Emergency Response Model (as seen originally in Table 5.1)

Minimum Activities for the SSM-based Emergency Response Management (ERM)
1. Ability to allow decision makers to: • Request, • Access and, • Assess information from various sources (including resources, external experts and instrumentation) related to a situation under alert;
2. Ability of various sources to collect information about a situation;
3. Ability to store information in one or more repositories;
4. Ability of authorised decision makers to plan and decide an appropriate action plan to tackle the situation based on what is available on them;
5. Ability to alert authorised decision makers if there is a situation that requires attention (including when an action plan decided is considered incorrect, incomplete or even if more resources are required);

6.	Ability to send the job plan to relevant and available resources (including operational units);
7.	Ability of resources or operational units to use allocated resources to take action once job plan has been received;
8.	Ability of resources to take a job on demand;
9.	Ability of operational units to report back of the job status including cases when more resources are required;
10.	Ability of emergency management authorities and resources to set up a code of practice in the form of a set of policies (including ethics and body of law).

The following process flow chart illustrates the aforementioned tasks and associated Grid-based technologies leading to the overall goal of helping emergency response management stakeholders to plan, control, collaborate, coordinate and communicate actions during emergency response operation.

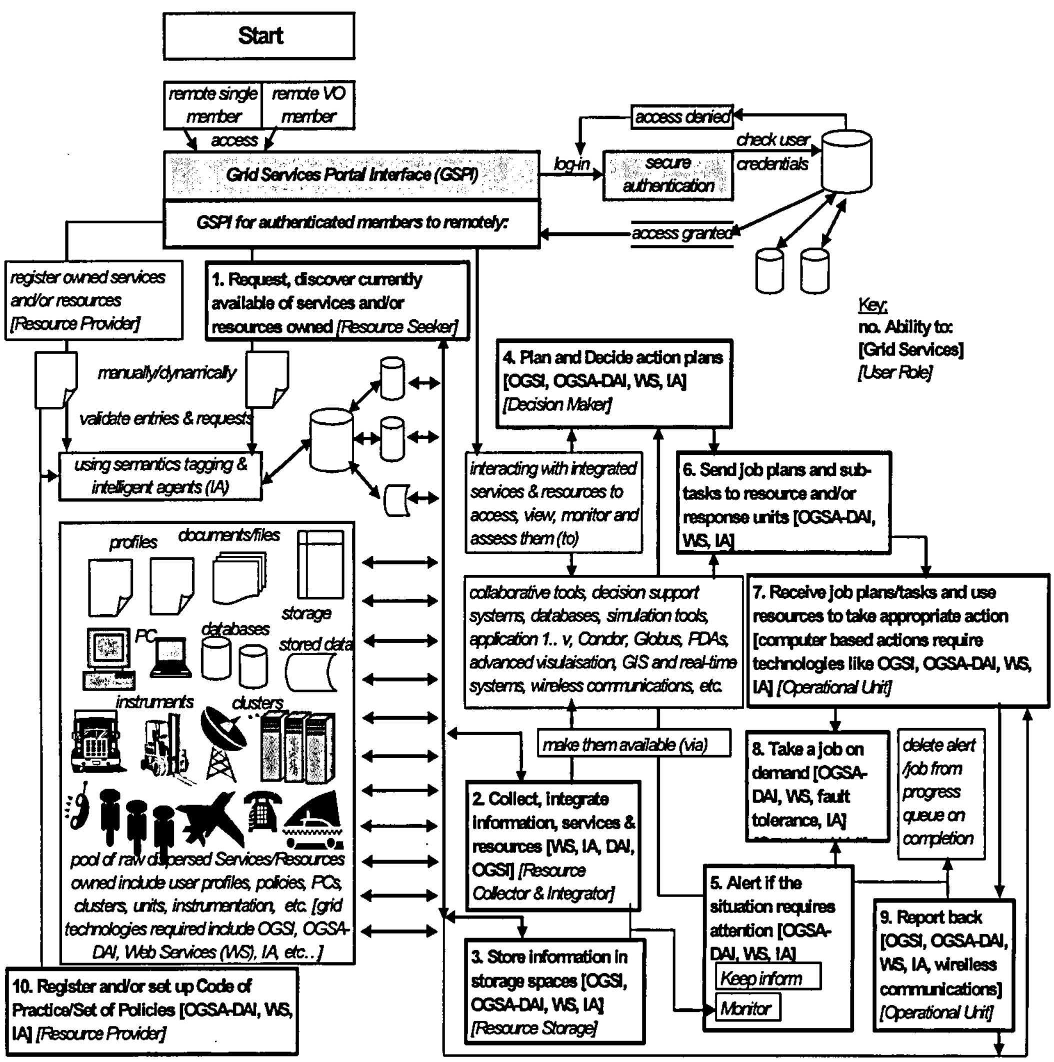


Figure 7.1: Process Flow Chart for the SSM based Emergency Response Model (ERM)

7.3.3 The Grid-Aware Emergency Response Model (G-AERM)

Apparently, the most important underlying opportunity in using Grid technology within the emergency response phase is that they will foster collaboration between decision makers and enable them to take more informed decisions. In particular, the deployment of Grid technology will facilitate seamless integration of what is availably known and therefore, enable the emergence of a relevant Virtual Organisation (VO) consisting of dispersed resources, operational units, ICT, instrumentation, experts and emergency response decision makers.

In turn, the VO will foster better communication, coordination and collaboration between its members. That is to say, decision makers as VO members will be able to utilise other VO member resources, request, access, assess and make use of more available resources at a given time in order to run complex and intensive what-if scenarios or other problem scenarios collaboratively and in parallel. This, in turn, will enlarge the actual search space boundaries within the problem space. Therefore, stakeholders will be able to search for resources or information about the emergency from a wider search space. The more resources that are available to consider, the larger the actual search space, which in turn will increase the opportunities for a better solution to be encountered by a decision maker. It is, therefore, believed that pairing the activities of the SSM conceptual emergency response model with Grid technology as seen in the process flow chart will enable:

A Grid-aware model that is owned, managed and operated by a VO that is dynamically formed by emergency management and other directly involved authorities when a natural disaster occurs. It is believed that the VO will improve the effectiveness and the efficiency of emergency response operations in terms of controlling, coordinating and communicating the emergency management procedures and the relevant resources, by:

- *Allowing utilisation of parallel distributed power processing to run complex tasks;*

- *Providing seamless integrated access to assess what is currently available and known and relevant to the emergency from multiple dispersed resources;*
- *Assisting the collaborative nature of the emergency response and rescue operations.*

The following statement outlines the Grid-Aware Emergency Response Model (G-AERM):

A Grid-Aware Emergency Response Model in the form of a VO to support the collaborative and dynamic provision and use of all currently available resources and instrumentation in order to dynamically integrate and seamlessly collect and store all data relevant to the emergency. In turn, the VO should allow the collaborative and collective assessment of this data, and if required to dynamically alert relevant registered and authorised resources and instrumentation including emergency management stakeholders about the emergency. Individual and/or collaborative resources, such as decision makers (as members of the VO) should be able to collectively access as much as possible integrated data from various relevant resources in order to collaboratively and collectively assess data and make an informed decision. This should then be forwarded and allocated dynamically to an appropriate and available collaborative operational unit(s) and/or other collaborative resource(s) as specified in the produced ER job plan. Following this, the operational unit(s) and/or other resource(s) have to take collaborative action(s) and run the allocated job(s) and finally, to dynamically report job(s) completion, failure or the need for additional resource(s). In the event of the need for external resource(s), the VO should dynamically alert relevant decision maker(s) to allow external resource(s) to collaboratively join the VO. Finally, for all these functions to run smoothly and according to the bodies of law, the codes of practice, the quality of service, the ethicality and other issues including environmental and humanitarian concerns, a set of pre-defined and/or dynamically generated policies as required appropriately should be embedded within the VO.

An outline graphical representation of the G-AERM is shown in Figure 7.2. It illustrates how the proposed Grid layer embraces all conventional ICT resources made available by participating (emergency response) authorities in order to respond to the disruption caused by the occurrence of a hazard. As time passes, the disruption reaches a number of peak levels required for it to progressively cease. The use of the proposed G-AERM will speed up the time required to manage the situation by shortening the disruption time compared to a situation where various conventional non-Grid tools have been used. This is due to the fact that decision makers and other members of the VO will benefit from taking remote decisions and actions dynamically and collaboratively from a far larger range of Grid-enabled resources (provided by the other VO members) that are free of ICT compatibility problems. Note that Figure 7.2 does not claim to visualise the gained time proportionally, but rather to illustrate its presence.

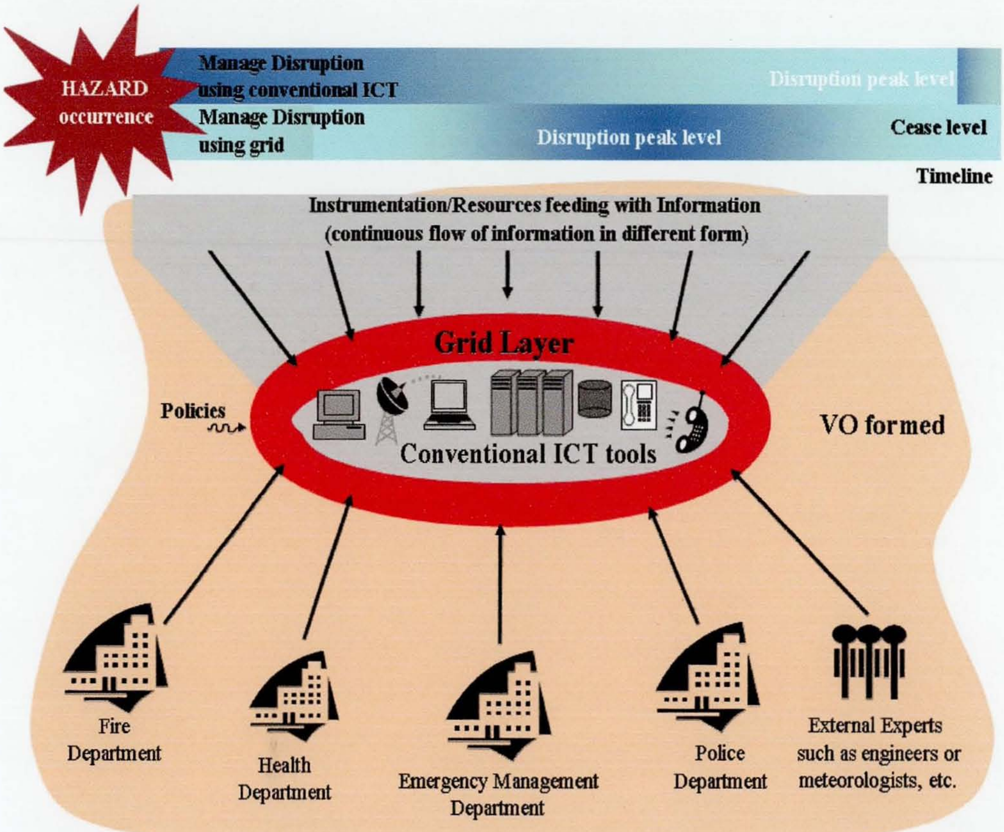


Figure 7.2: An Outline Graphical Representation of the Proposed Grid-Aware Emergency Response Model (G-AERM)

Clearly, a number of distributed resources and instrumentation generate a continuous flow of information in various forms. Such distributed and heterogeneous resources include, but are not limited to, instrumentation, such as telephone units, satellites, cameras, sensors, computers, databases and application software. The proposed Grid layer will enable the emergency response management team to make real-time intelligent decisions and act accordingly by assessing multiple dispersed resources. For example, the proposed G-AERM will enable the utilisation of these distributed and heterogeneous resources by feeding (manually or by pushing dynamically to) the VO members with relevant information in a more integrated form, as it may be required by an emergency management stakeholder. This will serve as a combined method of an oral and/or text messaging report, which are received by a member of an operational unit using a mobile phone. The Grid layer may also convert and save information, such as combined reports and associated images in a format that can be used (retrieved) for future reference if required.

Further to these, the proposed G-AERM will alert stakeholders of situations requiring urgent attention. It will also foster team working and collaboration between dispersed decision makers as VO members whose decisions may be dependent on each other's interactions. Resource integration at that level will support decision makers since it will allow them to view satellite images of the affected area, observe seismic activity, forecast, simulate and run what-if scenarios using other members' data modelling and mining tools (if they do not have their own), collaborate with (internal and external) experts and other authorities. Overall, the G-AERM approach as a whole will assist VO members to request and access as much information as is required and possible to acquire about a particular instance from different sources, and therefore to allow them to have a holistic view of the current situation. In turn, these will assist decision makers to prioritise and ultimately make more informed decisions, which will be disseminated to available rescue teams who will then take care of the operational tasks. The latter will be able to receive better-described ER job plans, push more meaningful reports and request more resources if required. Similarly, VO members would benefit from the use of each others' spare computational capacity to run highly intensive operations.

However, for the VO environment to operate within the proposed G-AERM environment, emergency management authorities, such as Fire and Rescue Service, Health and Ambulance Service, Emergency Management Section and Police department need to set a number of policies. To achieve this, stakeholders will be required to register their services using the “set of policies” activity. These policies will identify the quality of service to which each VO member will operate. Such quality of service will also include information related to authorisation levels. Authorities wishing to utilise expertise from external parties will also be required to seek and set up an agreed policy with the invited party. External resources may include, but not be limited to, structural and mechanical engineers, meteorologists, geologists, military or other, non-human resources.

Figure 7.3 illustrates the aforementioned types of interactions between VO members when using the proposed G-AERM. It also shows the main interactions between emergency response managers, operational unit leaders, external experts, data sources, model sources, data mining, computers and other instrumentation, such as satellites.

To this end, this can clearly be achieved through the use of the proposed G-AERM, which incorporates all the functions of the SSM-based conceptual ERM with additional benefits drawn from the utilisation of Grid technology. Emergency response operations as described in the proposed G-AERM, will clearly benefit from the utilisation of functionalities offered by data, computational and equipment (instrumentation) Grid. These will bring together incompatible distributed and heterogeneous instruments, hardware, application software and data for the benefit of emergency response operations. The detailed form of the technical solution embedded in the proposed G-AERM is described next.

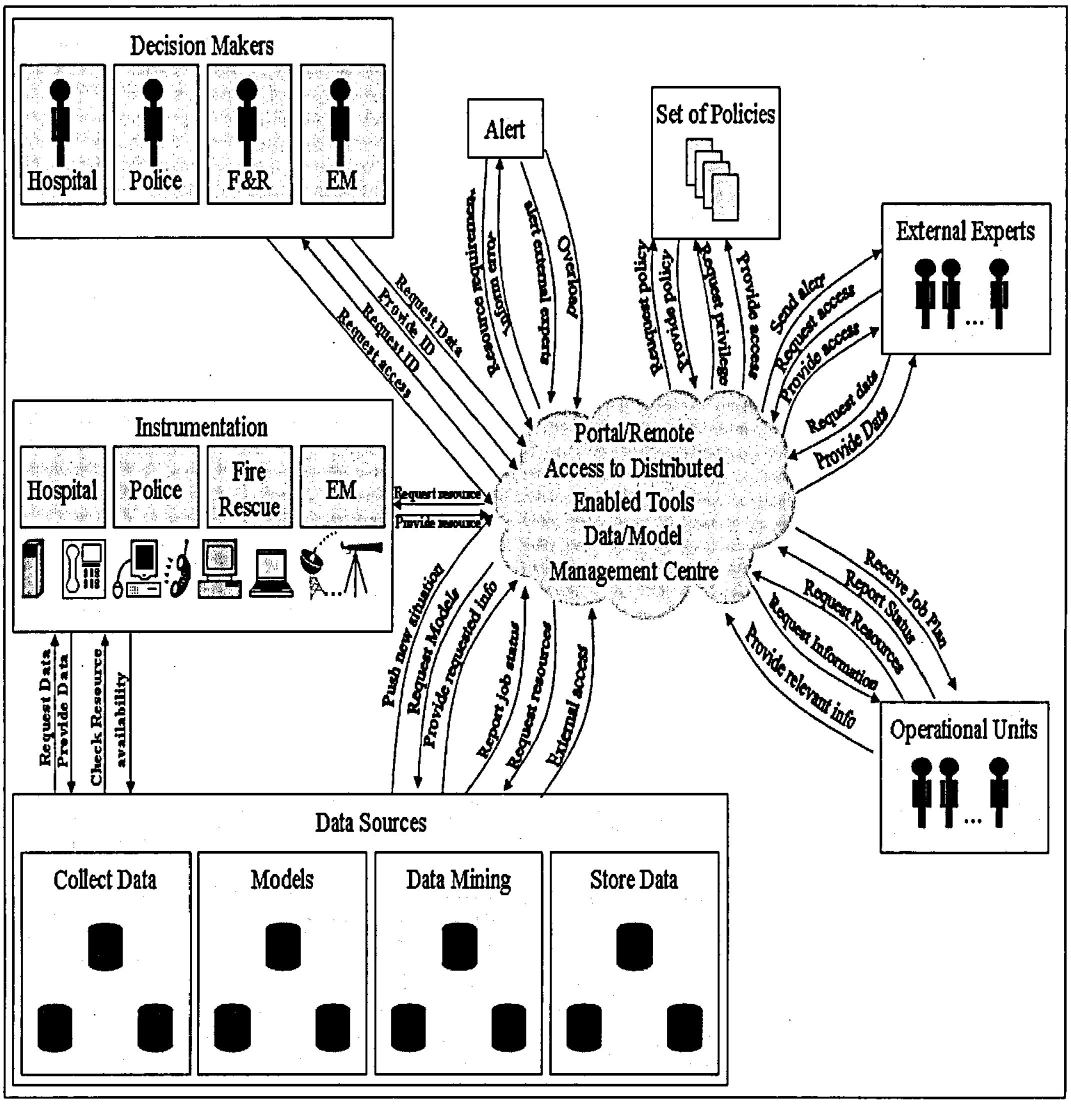


Figure 7.3: VO Members' Interactions when using the G-AERM

7.3.4 The G-AERM Architecture

Details of the G-AERM architecture, which could be used as the basis for a real-world application (Newman and Lamming, 1995) are presented in this section. A number of technical aspects associated with the G-AERM architecture are presented. In particular, the following sub-sections will focus on presenting the:

- Outline architecture of the G-AERM illustrating the main Grid standards and services available to the emergency response management VO members;
- Detailed architecture of the G-AERM illustrating a deeper understanding of how Grid-based functions and resource interactions – as these have been

described in the G-AERM – support each activity of the SSM-based ERM for the benefit of the emergency response management VO members.

To achieve this, integration of the proposed G-AERM with the process flow chart and detailed Grid related components identified in Chapter 6 have been used to detail the set of real-world and Grid-based technical requirements for the G-AERM architecture. This method is used to ensure that the G-AERM architecture is consistent and compliant with existing operational processes and practices currently used by emergency response management authorities. Finally, a number of real-world models' architectures, as seen in Chapter 6, have been taken into consideration when detailing the following sub-sections.

7.3.4.1 The Outline Architecture of the G-AERM

A real world application based on the G-AERM should facilitate access to either individuals or members of the VO formed. These members will be required to gain access to the G-AERM via a secure authentication mechanism, which will check the user's credentials. Checking will be performed using the user's credentials across a proxy database, which will hold the user's log-in details. It is expected that users will have registered their log-in details prior to their first attempt to use the system. They should be able to register their details and log-in via the Grid Services Portal Interface (GSPI). The latter should preferably be accessible via a Web browser, which supports a Graphical User Interface (GUI).

Once emergency management stakeholders are authenticated to the GSPI, they should have access to a number of services (access and assess data, resources, est.) – as detailed in the SSM-based ERM and G-AERM – via the embedded Grid functionality. That is to say, authenticated members will be able to register their owned resources including, but not limited to, their data sources, expertise profiles, collaboration tools, computers and other ICT. Registration of these resources will require some semantic tagging using XML-based metadata descriptions in the form of WSDL documents. These metadata descriptions will then be forwarded to a central database (proxy database), which will act as a "yellow pages directory". The latter is also known as a UDDI service and it will be used by others to identify, locate and use these resources. There may be a possibility that those members (service or resource providers) have already made descriptions of their owned resources to their local UDDI. In such instances, members will still have to register their resources to the main G-AERM's UDDI directory, which will then communicate with the local UDDI to identify, locate and give access to others interested in using them. Finally, the G-AERM should facilitate members with a wizard assisting them to semantically tag and register their resources.

Another service that should be made available to the G-AERM members is the ability to request the availability of resources including data, models, mining and collaborative tools, computational power, etc. Identification of requested resources should be based on the XML metadata descriptions that have been provided by resource owners during the registration phase. Again, a wizard assisting members as service and/or resource requestors (service or resource seeker) should be made available for their disposal. It is important to note that services and resources registered with the G-AERM are external entities and therefore, it is expected that the respective owners autonomously manage them. Figure 7.4 outlines the G-AERM architecture.

Upon a member's request, a Web Server broadcasting multiple Web and Grid Services compatible messages will be required. The GWSB (Grid and Web Services Broadcaster) will enable multiple requests for services and resources based on the XML metadata descriptions submitted by a VO member when registering or requesting them. For example, requesting a particular data service will require the searching of all the data sources that have listed in the main UDDI service, which will the be able to identify and locate the listed service in local UDDIs, if there are multiple results. Assuming that the member, as a requestor, is authenticated to access the requested data items, access will be provided via means of a virtualised data source. These are described in more detail in section 7.3.4.2.

Request for and delivery of, services and resources will be achieved via the communication between the GSPI, GWSB and registered services/resources. That is to say, a VO member requesting an XML metadata description based data service will be received by the GWSB. The latter will distribute the request identification (via the UDDI services) of registered services/resources via multiple XML based SOAP messages. Identified registered services or resources that are available will then become accessible via an XML based Web Services Interface. A similar functionality for computational and equipment Grid service providers and seekers will be offered. This will enable GSPI members to register and request computation power to run what-if scenarios and for others to view real-time images from a satellite.

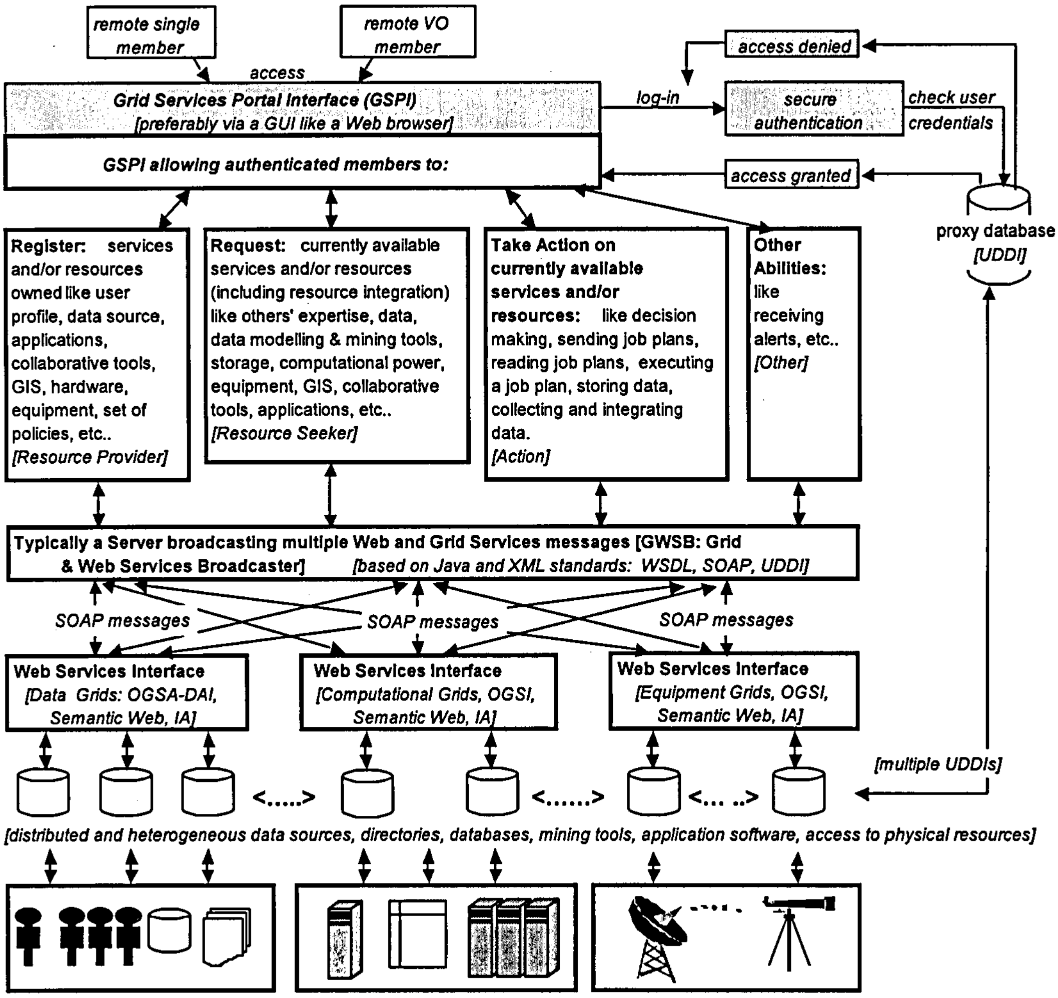


Figure 7.4: The Outline Architecture of the G-AERM

7.3.4.2 The Detailed Architecture of the G-AERM

This sub-section describes how the functionalities of various Grid services support all the activities as specified in both the SSM-based ERM and the G-AERM. It starts with the detailed architecture of the G-AERM for Natural Disasters, which can be then used as the full specification framework for the development of real-world G-AERM applications.

The expectation is that the VO will consist of single or multiple VO users, who will access the collaborative environment either as decision makers, invited external experts or operational unit leaders. It is also expected that decision makers will broadly follow current emergency management processes. That is to say, decision makers will be required to individually and/or collaboratively "access", "assess" and "decide ER job plans" via the provision and/or request for resources towards their goal fulfilment.

Users who provide resources over a Grid environment are termed "Service Providers" and they can provide data sources, model sources, data mining tools, power processing units, and other electronic, mechanical or human-related resources. Users who request resources over the Grid environment are termed "Service Requestors", and they may request any resource, covered by the set of policies that are provided through the Grid environment.

Figure 7.5 details the G-AERM architecture, the components of which are described below.

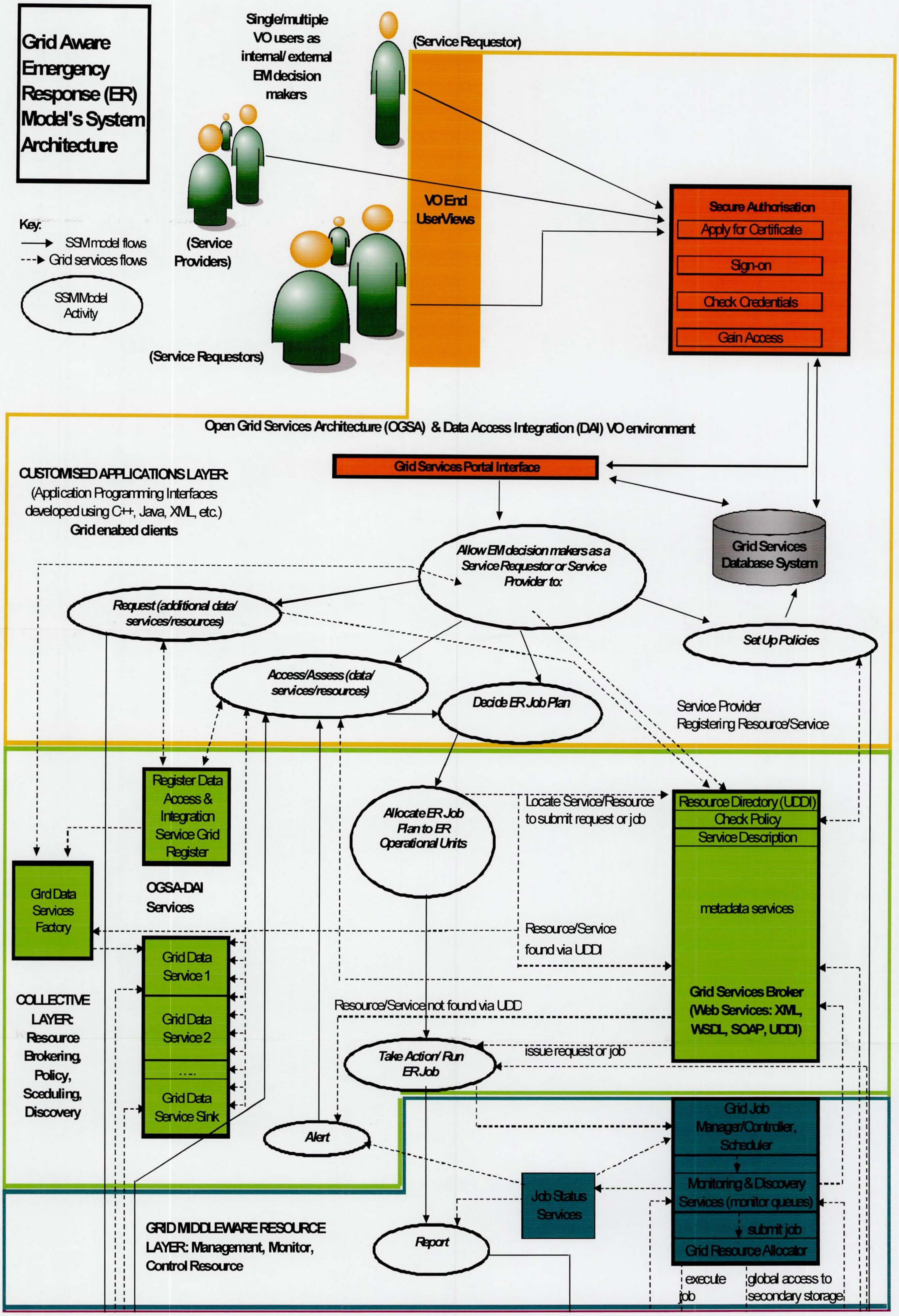


Figure 7.5: The Detailed Architecture of the G-AERM

- **Secure Access to the Grid Services Portal Interface (GSPI)**

Firstly, VO members will be required to access the Grid Services Portal Interface (GSPI) using the Secure Authorisation service. To gain access to the GSPI, perspective users need to apply for a certificate in order to be allowed to sign-on. This allows them to utilise single sign-on (SSO) so they will not be required to undertake multiple sign-on when accessing distributed services belonging to different owners.

As can be seen in the Connectivity Layer, the Grid system utilises the Grid Security Infrastructure (GSI), which allows reliable and secure access to resources using Public Key Infrastructure (PKI), Secure Socket Layer (SSL) and X509 certificates. Based on their authentication, the VO member(s) will have access only to services, which are registered to their account. These services are located in the Grid Customised Applications Layer and are described in the Grid Services database system, which recalls resource authentication via the "set of policies" service. For example, an emergency manager decision maker has the right to "access" a number of resources in order to "assess" them and "decide a relevant ER job plan". This is accessible by the emergency response operational units. The full description of each end user access view can be seen in Section 5.10.

When external expertise is required, the relevant leader is provided with the ability to amend or set up a policy at an appropriate level as required, in order for the invited external resource to join the VO environment. Similarly, leaders can amend or set up policies following the organisation hierarchy.

- **Grid Services Portal Interface (GSPI)**

This is located in the Grid Customised Applications Layer and its underlying specification relies on the Open Grid Services Infrastructure (OGSI), Open Grid Services Architecture (OGSA) and the Data, Access and Integration Services (DAIS) specification framework. In particular, a number of Application Programming Interfaces (APIs) have to be in place in order to provide access to the required services, such as access to dispersed data sources, model sources, mining tools, collaborative environments, application software, computational power and instrumentation. These APIs can be programmed using various languages, such as C++, Java, Python and XML.

- **Collective Layer (OGSA-DAI and Grid Services Broker)**

As mentioned earlier, it is expected that a number of resources will be available via the GSPI for decision makers to individually and/or collaboratively take them into consideration in order to produce an emergency response job plan together. In this respect, a Service Provider as a decision maker or else will need to register their resources/services to the resource directory (UDDI) and specify the policy in which the registered resource/service will be used by others. This will enable other parties to locate registered resources/services.

In particular, to register resources/services, the Service Providers will be required to describe their resources/services using the Web Services Description Language (WSDL) in order to define how the service is to be used by others. Registered services/resources can be found using the Grid Services Broker, which includes registered services/resources metadata services (XML), which are connected to a Service Requestor using the Simple Object Access Protocol (SOAP). The Grid Services Broker is located in the Collective Layer.

On the other hand, an individual or a group of EM decision makers as Service Requestors will need to "access" a number of appropriate and relevant resources/services including data sources, model sources, data mining, decision support applications, processing power and other physical resources in order to "assess" the current situation and "decide the best possible ER job plan". The following list specifies the exact steps and the Grid technicalities required for an individual Service Requestor to request access to appropriate data/resource services using the OGSA-DAI specification framework, which operates under the Web Services Resource Framework (WSRF):

- EM decision maker as a Service Requestor will need to request the Data Access and Integration Service Grid Register (DAISGR) for the source of data about a particular instance like X;
- The DAISGR will return a handler to the Service Requestor;
- The DAISGR will send a request to the Grid Data Services Factory (GDSF) to access the relevant data sets that are registered with it;
- The GDSF will create a Grid Data Service (GDS) to manage access to relevant data sets;
- The GDSF will return a handler of the GDS to the EM decision maker;
- EM decision maker as a Service Requestor will perform the query to the respective GDS using a database language such as Structured Query Language (SQL);
- The GDS will interact with the available dataset(s);
- The GDS will return the query results in a XML format to the Service Requestor.

In the event that the GDSF has identified more than one of the data sets (for example, GDS 1: Grid Data Service 1, GDS 2: Grid Data Service 2, etc.) that contain the relevant information, the EM decision maker, as a Service Requestor, will either select a particular GDS (for example, GDS1) based on his preference(s) or request for data to be integrated into the GDS sink. That is to say, a GDS sink will handle the communications between the EM decision maker and the multiple GDSs (GDS1, GDS2, etc.), which will further interact with their respective data source sets in order to return query results in a XML format to the EM decision maker.

Following the process described above, an EM decision maker will be able to "assess" data related resources (using emergency response operation current practices and conventional methods) in order to "decide an ER job plan", which will be "allocated" to the respective "ER operational unit" which will take care in "taking action and run the ER job", alongside the instrumentation/resources allocated to this job.

The Grid Services Broker, described earlier, enables the Semantic Web functionality via the use of Intelligent Agents to identify and locate both data and other types of resources. These may include data harvesting or a requirement for processing power to, for example, run highly intensive application jobs, such as a simulation to forecast the optimum (shortest) time to safely evacuate a number of trapped people and suggest the optimum evacuation route.

To achieve this, the Grid Services Broker operating under the WSRF will need to locate appropriate services/resources required to undertake action as specified. The Grid Services Broker will check resource availability through its UDDI directory, the service description and the policies, using XML-based metadata descriptions. If the job is issued to human-related resources and these resources are found, the Grid Services Broker will issue the request to "run the ER job" by the relevant human-related operational unit.

If the job is issued to a computer-based resource, to run a simulation scenario as described earlier and these computer based resources are found, the Grid Services Broker will issue a request to "run the ER job" via the Grid Job Manager, which will act as a non-human operational unit leader. The Grid Job Manager is located in the Grid Middleware Resource Layer and it takes responsibility of controlling, managing, monitoring and scheduling (computationally related) issued jobs.

If resources are not found to satisfy the policy requirements or not found at all through the UDDI directory, the Grid Services Broker will "alert" decision makers to take appropriate action, such as to negotiate policy requirements and/or seek alternative resources.

- **Grid Middleware Resource Layer**

Once a computational related job is issued to the Grid Job Manager via the "take action/run ER job" and the Grid Services Broker, the Grid Job Manager will need to check its scheduler and its job queues in order to discover the resource (for example, a cluster) and ultimately submit the ER job via the Grid Resource Allocator. Once the resource is found, the Grid Resource Allocator will send the job to the resource in order to execute the job. Initially, the job will be sent to the Master node, which will co-ordinate and spread sub-job tasks (as defined in the job plan) to the cooperating slave nodes. If a sub-job is interrupted for any reason, the Grid Manager will order it to retry job completion for a predefined number of times. The Grid Monitor Services will alert the Grid Manager (for example, the cluster master node) in the event that the retry has been unsuccessful. In such a case, the embedded Grid Services fault tolerance will request the Grid Manager to firstly save the partially completed work to a secondary storage and secondly, to alongside the Grid Resource Allocator, to identify and issue an alternate path to execute the remaining sub-jobs. Once the job is completed, the Monitoring Services, which are located at the Grid Job Manager, will inform the Job Status Services, which will further notify the "Report" system activity, which will be stored to the data sources of the 'Collect' SSM activity. The Job Status Services will concurrently inform the Grid Job Manager that resources are available for future use via the Monitoring and Discovery Services. If a job has not been completed, or has failed because no resources have been found available at the specified time, the Grid Controller will keep the job in the Monitor Queues and will attempt to identify alternate solutions for a predefined number of times. In the case that the process is unsuccessful because of the expiration of the numbers of attempts or because of policies specified in the job plan, the Job Status Services will raise an "alert".

- **Fabric Layer: Resource/Service and Instrumentation Providers**

This layer consists of the currently available EM distributed and potentially incompatible instrumentation/resources owned by different authorities, such as the GSCP, EMS, Police, Fire and Rescue, and Health and Ambulance Services. Their instrumentation/resources include, but are not limited to, VHF radios, mobile phones, landlines, vehicles (police, cars, ambulances, etc.), aircraft, satellites, computers, clusters, campus Grids, data, earth observation systems, weather stations, seismographs, geographical information systems, satellite phones, pagers, TV channels, military equipment, radio stations, data sources, model sources, data mining tools, etc. It is expected that human-related resources, such as operational units and external experts will be notified about their duties via the appropriate ICT equipment as mentioned above.

These instrumentation/resources – depending on their physical nature – will be registered in the G-AERM's Data Grids, Computational Grids or Equipment Grids so they can be accessed accordingly. These will then feed the "collect data" SSM activity with appropriate information about the natural phenomenon and the current situation. These types of information are then stored in database or model-base management systems via the "store collected data" SSM activity. This activity functions as the gateway for the OGSI, OGSA-DAI Services Specification and the Grid Services Broker to locate and make instrumentation/resources available to the decision makers via the "access/assess data" SSM activity in order to "decide ER job plan".

7.4 Summary

This Chapter incorporated the SSM emergency response model (ERM) formulated in Chapter 5 with Grid technology as a method to allow emergency management operations to improve effectiveness and efficiency in terms of controlling, coordinating and communicating emergency management procedures and relevant resources. The proposed Grid-Aware Emergency Response Model (G-AERM) for natural disasters supports the collaborative and dynamic provision and use of all currently available resources and instrumentation in order to dynamically integrate and seamlessly collect, access and assess collected and stored data from multiple distributed ICT sources in order to decide and issue an appropriate ER job plan to relevant operational units. On this basis, Chapter 7 described the G-AERM's architecture detailing the Grid technicalities involved to serve as the framework for the development of real-world applications that will improve current practice. The next Chapter, Chapter 8, defines the criteria on which the G-AERM for natural disasters has been evaluated. Further to this, it presents the details of the evaluation exercises and critically discusses the findings. Finally, Table 7.2 summarises how each of the aforementioned Grid component links to the specific set of requirements for the G-AERM.

Table 7.2: Grid based Components Used to Resolve Current ICT Limitations and Link to the Identified Set of Requirements for Emergency Response Management

SET OF REQUIREMENTS for an Emergency Response Model							
1. Emergency management authorities stakeholders to work remotely and collaboratively in order to plan, control, coordinate and communicate relevant actions in a more effective and efficient way;	2. Stakeholders to dynamically receive the most up-to-date information of what is the current situation (upon request);	3. Stakeholders to dynamically receive the most up-to-date information in relation to what resource is available to use (upon request);	4. Stakeholders to work in an environment that is free of any ICT compatibility problems;	5. ICT resources to dynamically collect, store the most up-to-date information of what is the current situation;	6. ICT resources to dynamically assess and allocate incomplete jobs to other available resources if they become unavailable;	7. ICT resources to interoperate in a compatible way;	8. All resources to dynamically and collaboratively work in an environment as defined by the set of policies.

Minimum Activities for the SSM based ERM	GRID Components of the G-AERM Architecture linking to the Set of Requirements
1. Ability to allow decision makers to Request, Access and Assess information from various sources (including resources, external experts and instrumentation) related to a situation under alert;	[Access to the Grid Services Portal Interface (GSPI)] [Access Authorisation via a Credential Authentication Mechanism using SSO, GSI, PKI, SSL and X509] [All Authenticated VO members require to register their User Profile and Expertise. All Services Providers required to register owned services and resources using XML based metadata descriptions (WSDL, semantic tagging) to the UDDI service (proxy database)] [All Service Requestors need to specify whether they require access to Data, Computational or Equipment Grids] [All Service Requestors need to specify their requests using XML based metadata descriptions to the proxy UDDI] [The GWSB will send multiple SOAP messages to the Grid Services Broker (GSB) in order to identify and locate registered and available services/resources via multiple registered UDDIs] [Data Requests can also served using the OGSA-DAI specification: requests to be registered with the DAISGR and GDSF. GDSF will generate a GDS. Requestor can use a query language like SQL to access the GDS. Results will be displayed on the GSPI using an XML] [Assessment will be via current conventional ICT like a GIS, DSS or by using others' VO members DSS or data mining tools]
2. Ability of various sources to collect information about a situation;	[Authenticated Access to GSPI using methods as described above] [Collection, integration and virtualisation from multiple distributed, heterogeneous, and independently managed instrumentation based sources require OGSI, OGSA-DAI, GSB, GDS, SOAP messages]
3. Ability to store information in one or more repositories;	[GSB to contact the Grid Job Manager (GJM) and Grid Manager Controller (GMC). The Grid Resource Allocator (GRA) component of the GMC will (by the means of SOAP messages) allocate the store request to the identified repository (a database for example). The Grid Services Monitor (GSM) will monitor job status and in the case of an unsuccesfull attempt will alert the GJM] [For an alert process see item 5 below]
4. Ability of authorised decision makers to plan and decide an appropriate action plan to tackle the situation based on what is available on them;	[Planning requires collection, integration and virtualisation from multiple distributed, heterogeneous, and independently managed instrumentation based sources using OGSA-DAI, GSB, GDS, XML] [Assessment ability requires other VO members expertise and current conventional ICT like IA, GIS, DSS or others' VO members DSS or data mining tools] [Embedded to the GSPI video-conferencing tools would assist in collaborative assessment, job planning and decision making] [Other collaborative and co-ordinated support mechanisms include concurrent view of concerned data, images and tools from all the decision makers in real-time] {For co-ordinated computer related tasks see item 8 below]
5. Ability to alert authorised decision makers if there is a situation that requires attention (including when an action plan decided is considered incorrect, incomplete or even if more resources are required);	[Interested VO members will receive real-time data] [Non real-time data sources will send updates to interested parties if these have been registered via the UDDI] [GSB and/or GSM (depending on task) will monitoring the status of new entries (new data coming from a satellite for example). Assessment of new entries will be done by special validation checking on both the GWSB and member's GSPI level but most importantly via DSS, data mining tools and IA. These technologies should make real-time comparisons and assess whether situation is critical. In such case, GSB and/or GSM will generate a SOAP message alerting interested VO members of the problem (a VO member will receive an XML based alert message via their email, GSPI screen or PDA)] [Computer related failures require failure detection or fail-over mechanisms. OGSI/Fault Tolerance service can be enabled via GSM that will retry to rerun the job for a numder of predefined times. If the problem persists, GSM contacts GJM. GJM contact GRA to re-route the job. GRA contacts Grid Scheduler and places the job in the Queue else will raise an alert as described above]
6. Ability to send the job plan to relevant and available resources (including operational units);	[Request resource availability using methods described earlier (OGSA-DAI or via GSB)] [Identify job receiver intelligently (if required) using IA via the GSB and the proxy UDDI. GWSB to send SOAP messages to multiple dispersed UDDIs in which disperse available job receivers have been registered with. On receiver's identification, decision maker will attach and send the job plan specified in an XML based message (using a wizard, GSPI members do not need to have any programming skills at any stage of operating the GSPI) will alert operational unit (job's receiver) via email, GSPI or PDA]
7. Ability of resources or operational units to use allocated resources to take action once job plan has been received;	[Use of resources requires resource identification a described earlier] [Human related co-ordination requires current colaborative tools, access via GSPI and GSB] [Non-human but data related co-ordination requires OGSA-DAI and GSB, again in the way as described earlier] [In the case where GSPI is down, VO member have to move to another terminal, location or use a PDA to access it via wireless communications] [For computer based jobs see item 8 below]
8. Ability of resources to take a job on demand;	[Computer related co-ordinated jobs require the additional services from the GJM, Grid Scheduler, GMC, GRA and GSM in order to negotiate resource availability and policy making] [Identification of available resources in a distributed environment (take parts of a job) require GSB and the proxy UDDI. GWSB to send SOAP messages to multiple dispersed UDDIs as described earlier] [Highly intensive computer tasks (computational grids) require the additional services of the job's workflow, the grid status and the queing services] [Job submission to the GJM can be done in any format like C++ or Java specifying job parameters] [It is expected that GSM have registered the kind of jobs or services they can execute using the Service Provider registration method as described in item 1 above]
9. Ability of operational units to report back on the job status including cases when more resources are required;	[Access GSPI remotely via a terminal or a PDA] [Use of SSO, SSL PKI and job identifier to access the correct job status form] [Send form to GSPI] [GSPI takes job identifier and requests proxy UDDI to identify receiver via the GWSB] [GWSB locates receiver via the GSB (SOAP message)] [Computer related reports report back to the GSM and GJM] [If job is incomplete or failed see item 5 above] [If job has been completed, resource will become available in real-time and it can be considered for another task. GWSB will send a SOAP message to the proxy database and immediately render availablity to the GSPI]
10. Ability of emergency management authorities and resources to set up a code of practice in the form of a set of policies (including ethics and body of law).	[Register and/or amend a code of practice via the same Service Provider form as described in item 1 above] [For any type of service request, query will be filtered by the analogous set of policies unless request is on the same resource level in which SSO and the proxy UDDI will keep the settings]

Chapter 8 Evaluation of the Grid-Aware Emergency Response Model (G-AERM)

8.1 Introduction

This chapter is concerned with the evaluation of the Grid-Aware Emergency Response Model (G-AERM) for natural disasters, which was formulated and presented in Chapters 5 and 7 of the thesis. This step is associated with the fifth objective of the study, as presented in Chapter 1. This covers the evaluation of both the conceptual and technological solutions proposed for the model. Therefore, two sets of instrument tools have been produced and two groups of experts have participated in the evaluation exercise. These include emergency management stakeholders and Grid technology experts. The following sections present the evaluation exercise in terms of its criteria, the evaluation questions, the participants and the findings. The findings are analysed presented using SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis and a critical discussion of the results is presented in Section 8.5.

8.2 The Evaluation Exercises

Soft Systems Methodology's (SSM) epistemology suggests that the evaluation of the proposed solution has to be done in terms of the three Es – effectiveness, efficiency and efficacy. However, as the focus of this research work was not to create a real-world application – but to propose the concept and the most appropriate technology for a single model to accommodate the activities of emergency response operations, the evaluation took place in terms of effectiveness and efficiency only. Efficacy has not been evaluated as it is related to whether the real world application is of an operational order. Therefore, the evaluation exercises conducted were:

- Evaluation exercise in relation to the conceptual G-AERM;
- Evaluation exercise in relation to the technological considerations, that is to say the architecture of the G-AERM.

It is important to note that the G-AERM includes the SSM-based conceptual Emergency Response Model (ERM).

8.3 Determination of the Evaluation Criteria

The criteria used for the evaluation of the G-AERM focused on the extent to which it assists emergency management stakeholders during emergency response operations when a natural disaster occurs in functioning more effective and efficient. In particular, the evaluation was concerned with the degree of satisfaction of the emergency management stakeholders in using the proposed model, as well as the degree of satisfaction of Grid technology experts in relation to the proposed model's architecture. These involved knowledge of the availability and quality of resources and related information on the emergency and the natural phenomenon itself. It also involved the speed with which emergency management stakeholders become informed about the availability of their resources, as well as about the information related to the current situation and the natural phenomenon itself.

The evaluation criteria also included the speed of making informed assessments and decisions and the speed of communicating emergency response job plans, as well as the effectiveness and efficiency of G-AERM's infrastructure in relation to the application of Grid technologies. In particular, the G-AERM has been evaluated in relation to the activities required by emergency management stakeholders to manage an emergency response operation (see Table 5.1). Additionally, the evaluation exercise also explored whether the limitations identified by the emergency management stakeholders (see Table 4.5) have been addressed through the proposed G-AERM's architecture.

Overall, the evaluation exercise was concerned with whether the proposed G-AERM further supports the overall goal of emergency response management stakeholders to plan, control, collaborate, coordinate and communicate actions during emergency response operations. To this end, the G-AERM has been evaluated in terms of the following criteria:

- The degree of satisfaction with the overall technological solution provided by the G-AERM and;
- The degree of satisfaction with the way and speed in which:
    - decision makers are getting informed about the availability/status of resources;
    - decision makers are getting informed about the current situation;
    - emergency response operational units are getting informed about job plans;
    - collaboration is achieved between emergency management stakeholders during the emergency response operations.

8.4 Evaluation of the G-AERM

The following sub-sections are concerned with the evaluation exercises conducted.

8.4.1 Evaluation Procedure

The evaluation involved the formulation of two evaluation tools that consist of two clusters of interview questions and the identification of two groups of experts to participate to the evaluation exercise. The first evaluation tool was concerned with the effectiveness and efficiency of the concept of the proposed G-AERM and the evaluation was conducted with emergency management stakeholders. The second evaluation questioner was related to the technological Grid-based architecture of the G-AERM for its real-world application. The evaluation participants in the second evaluation exercise were people with background related to computing and information systems, with particular expertise in Grid technology.

8.4.1.1 Evaluation Exercise in Relation to the Concept of the G-AERM

This involved one-to-one interviews with emergency management stakeholders from both Greece and England. These participants included the following:

Greece:

- The Educational Consultant of the Pedagogical Institute of Greece, Leader of Civil Protection of the Pedagogical Institute of Greece, Member of the 1st

Scientific Community of the Greek Earthquake Planning and Protection Onganisation (EPPO);

- The Head of Civil Protection Department of Viotia.

England:

- The Director of Emergency Management Department of the Leicester City Council;
- The Head of the Planning Department of the Leicestershire Fire and Rescue Service.

The one-to-one interview questions were as follows:

Free written transcriptions were made of the oral discussion and these are documented in Appendix IV. The following paragraphs highlight the major issues:

- **The proposed solution stands as a G-AERM that it is owned, managed and operated by a VO that is dynamically formed by emergency management and other directly involved authorities when a natural disaster occurs. This will improve the effectiveness and the efficiency in terms of controlling, coordinating and communicating the emergency management procedures and the relevant resource during emergency response operations in a distributed fashion (any time, any place, anywhere).**
    a) **Are you aware of any single IT system that accommodates all the activities as listed in table 1?**

All four interview participants stated that they were not aware of any single IT system that accommodates all the activities listed. One participant pointed out that they were looking forward to sharing relevant information in the future.

- **The proposed model has the ability to collect relevant information about the event and run a preliminary assessment to identify the level of the emergency. When there is the need for response it identifies the**

appropriate emergency management stakeholders and alerts them through their personal mobile devices (laptops, PDAs, desktops, mobile phones etc). Emergency management stakeholders could run a meeting to assess and control the emergency by making decisions and organising the response operation from wherever they are located using a series of alternative methods including verbal, visual and written forms through the above mentioned mobile devices. This provides stakeholders with the ability to be on their own bases, on the move, or even on the area of the emergency and still to have access to important information (own or others' information), as well as to participate to the meeting.

a) Do you find this approach more efficient?

b) Is the identification by the G-AERM of the most appropriate people to participate to the meeting going to help to make more informed and accurate decisions?

c) Is the ability of allowing meeting's participants to be located to places in need and still have access to information a more convenient approach?

d) Do you think that the approach as a whole will enhance your good practice in any other way? Specify.

All participants fully supported the view that the distribution of emergency management decision makers is a more efficient way of managing the situation. In particular two of them pointed out that this would be a more efficient approach as it will definitely save time. One of the other participants (from Greece) said that this function will be very useful – in particular for Greece – as there are many islands and tall mountains and transportation from one place to the other is sometimes very difficult or even impossible. The fourth participant found G-AERM's function of supporting virtual meetings during assessment and decision making very efficient but, believes that, if required, stakeholders should be able to physically meet in some cases to make decisions. In relation to the identification by the G-AERM of the most appropriate expert to participate in the assessment and decision making process, all participants stated that this would help considerably during emergencies, as having the right people is the key to the decision making process. They explained that currently they have the details of all potential experts stored in data sources and have to manually search and identify the most appropriate one for each situation. They also believed that the automated identification will save time and will be more accurate. With regard to the third part of the question all participants found that it will be a more convenient approach as a whole. In particular, one participant stated that it is convenient for the decision makers to be located to places in need; however this function needs to be in line with the bodies of law of the country and with the regulations of the authorities. The other three participants pointed out that it will be more convenient approach, as access to departmental information is sometimes essential during decision making. Additionally, operational units need to be on the move and still have access to information. Finally, one participant did not believe that G-AERM's abilities will enhance practice in any other ways, and another highlighted that real-world application of the G-AERM need to be created in line with the bodies of law and the departmental regulations of the authorities involved. The two remaining participants believe that these abilities of the G-AERM will enhance and promote good practice, as any real time information gives a decision maker the ability to make more informed and dynamically-driven decisions, which is beneficial.

- **According to the proposal, the available resources of each department involved in the response operation are stored and up dated in a database, owned and managed by each department. During the emergency operation all these databases work together and provide the decision makers with all the currently available resources. Resources appear in terms of availability, expertise, location, current status and ownership. Additionally they appear as unavailable when a job plan has been allocated to them and until the time they report back their job completion, and therefore, their availability. Each decision maker is able to access this data and all together is able to assess it without the need for a physical meeting.**
    a) **Could this ability offer you exact information of currently available resources?**

b) **Could the knowledge of the exact status of resources at any time further support your decision making process in terms of making more informed and timely fashioned decisions of action? In other words, do you think that such approach will enlarge your space to make a more informed decision?**

c) **Could the detailed description of resources support you in mapping the process in relation to expertise and availability, prioritise tasks, decide and allocate job plans to specific units and move on to your next task? In other words could it help you to be more productive and more organised (in terms of managing the operation)?**

d) **Do you think that this function could minimise the possibilities of erroneous decisions in terms of expertise and availability of resources (by alerting you if wrong choices-decisions are made)?**

e) **Do you think that the approach as a whole will enhance your good practice in any other way? Specify.**

One of the four participants said that they already use a similar service however; operational units have to provide feedback to the control centre – in the form of risk assessment – every twenty minutes and based on that, decision makers are informed about the status of resources. Another participant said that in theory this function would be very useful during the decision making process however, he is not sure that operational units can provide feedback to the system during the operation. He suggested that they need to be trained and provided with convenient communication mediums. The other two participants found that this approach could provide exact information about currently available resources. The response to the second part of the question was positive from all the four interview participants. They all thought that if resources of all departments are accessible to all relevant stakeholders and operational units inform the model about their status, then the search space will be wider and this will further inform the decisions to be made. In relation to the third part of the question, all four participants found this function helpful, as it would allow them to do forward planning, which according to one participant is very important for emergency response management. Finally, they all supported that this function will minimise the possibilities of erroneous decisions in terms of expertise and availability of resources.

- **The G-AERM is able to provide you with exact information. For example, if testing with health and ambulance service, it will be important to know bed and staff availability of local hospitals and health centres, evacuation plans and nearest route and current traffic situation, surrounding support or other general constrains/conditions. The model will therefore generate the area's route map according to current traffic and nearest route to assist a driver reaching the desired destination. This information is provided to the stakeholders during the decision making process.**
    a) **Do you believe that such functions allow you to allocate relevant job plans to operational units (ambulance service) in a more timely fashion?**
    b) **Do you believe that operational units will benefit from such services?**
    c) **Does this function minimise erroneous decisions and time required for the execution of a task?**
    d) **Do you think that the approach as a whole will enhance your good practice in any other way? Specify.**

All four participants were positive about the above functions of the G-AERM. Two out of four answered "yes", one "definitely" and the fourth said that although they do not face problems during operations, such functions could improve their performance. They also believe that operational units will benefit, as they will know in advance valuable information. From the answers provided by all four participants, these functions could minimise the time required for the execution of relevant tasks.

- **The G-AERM proposes that the sum of the relevant policies and the bodies of laws (ethics and legislations) that you have to follow during the operation are stored in each department accordingly. However the model is able to retrieve them automatically, or on demand, according to the**

process and needs, to automatically filter them in such a way to cross reference decision taken. In addition to this, when there is the need for a new, not predefined policy, the model could contact the relevant authority to ask for approval, according to your demand.

a) **Would this function be of any advantage for your actions during the response operation and how?**
b) **Will this function address legal-ethical enquires that you may have during the operation in a more timely and informed fashion?**
c) **Will this approach guide people involved to the operation avoiding inappropriate actions?**
d) **Would it be useful allowing relevant parties to update policies on demand (experts)?**
e) **Do you think that the approach as a whole will enhance your good practice in any other way? Specify.**

Two of the participants stated that the on demand requirement for a policy or law will assist the operation. Participants from Greece said that although this would be a useful function it will not work in Greece, as someone cannot ask for law alterations in this way. In order for this to work in any real-world application of the G-AERM, it needs to be developed in relation to the relevant bodies of law, or the relevant bodies of law need to be alternated to support this function. All four agreed that if this function were in operation it would support them in avoiding making erroneous decisions as it would stop the process if not in line with the bodies of law. They also thought that it would be useful to update policies on demand, as long as the whole process works in line with the relevant laws.

- **It is proposed that the communication between the parties involved to the operation is done in written forms, or in oral transformed by the G-AERM in written ones, as an attempt to minimise the oral forms of communication and therefore misunderstandings and the transfer of objective information. Thus, reports and on screen communication will be available by the proposed system between all the parties involved (filtered by user roles - decision makers, operational units, external**

experts). Additionally, the model supports the transmission of real time pictures and videos related to the phenomenon and to the areas of the emergency. These will be achieved through the integrated use of mobile phones, computers, fax, picture messaging, video, VHF radios, portable screens and others.

a) **Do you believe that this could lead to a more effective and efficient way of collecting information about the current situation?**
b) **Do you believe that this method will assist in avoiding the transmission of subjective information?**
c) **Do you think that this function will assist you in having more accurate picture about current situation which will lead you to a more informed decision making?**
d) **Do you think that the approach as a whole will enhance your good practice in any other way? Specify.**

All four participants agreed that if the G-AERM minimises the oral forms of communication through written ones and through transmission of real time pictures and videos related to the phenomenon and to the areas of the emergency, the collection of information will be more effective and efficient. They also believe that this will assist in avoiding the transmission of subjective information, which is always an issue during response operations. Two participants were concerned about how cameras would be installed in forests and in general remote areas, but in general they all believe that this function will assist in having more accurate and informed picture of the current situation.

- **The operational units receive the allocated job plans through their part of the G-AERM and they take the appropriate actions. The job plan describes exactly the job needed to be done, by specifying the operational unit/s which needs to carry the job and the timescale. When they complete the job they report back to the model of the job completion and automatically, they are considered as an available resource. If the job can not be completed they report the reasons, the need for extra support**

(more/different resources), or the job failure. In these cases this data is collected by the G-AERM and goes again through the assessment process. When the decision makers allocate a specific job plan to an operational unit for a specific time limit the G-AERM knows that this unit is engaged doing this task. Similarly, it will know by the report function when this unit will become available again and therefore decision makers could proceed to the assessment taking into consideration this unit for another job. The model could forward the new job plan to the specified unit once they have submitted the report stating the successful completion of an allocated job.

a) **Do you think that this could be an advanced method of communication in terms of objective, accurate and on time transmission of job plans?**
b) **Do you think that such a system will assist in error handling?**
c) **Is this method effective and more efficient in terms of knowing exactly when, where and what it is available at all the times?**
d) **Is it going to assist decision makers to make more informed decisions and operational units to know exactly the details about their allocated task?**
e) **Do you think that the approach as a whole will enhance your good practice in any other way? Specify.**

All four participants were of the view that the above functions of the G-AERM will serve as an advanced method of communicating job plans, and will assist in error handling. It was also considered far more effective and efficient than current practice and will assist decision makers in making more informed decisions whilst operational units will be able to know exactly how, where, when and what they need to do.

- **In situations where external expertise is required (meteorologists, engineers, doctors, etc) the G-AERM, according to your demand, alerts the pre-defined expert, and he is then able to log in to his part of the model (as this has been predefined by the policies) and to (alongside with**

you) collaborate towards the assessment of a specific situation, to the decision making process, or to assist decision makers with his expertise to specific enquiries towards a decision (VO).

a) **Could the VO approach assist in a more informed decision making?**
b) **Is the VO method more efficient in terms of finding, contacting and collaborating with the most appropriate external expert?**
c) **Do you think that the approach as a whole will enhance your good practice in any other way? Specify.**

All four participants strongly believed that the VO approach could enable far more informed decision making, and in finding and contacting the most appropriate external experts. However, one participant pointed out that the G-AERM also needs to support face-to-face communication, as it is sometimes vital during operations.

- **The G-AERM proposes that in situations where there is the need for extra computing power to run jobs, the computing power of other organisations will be used. As an example could be considered a bad affected building that is ready to collapse. If the details of the building, such as material specifications, technical drawings, evacuation plans and any other relevant details are identified by the model, along with the cooperation of external experts (structural engineers) it will calculate the available time that the rescue teams will have in order to enter and evacuate the building safely and on time, before its collapse and it will propose the safest possible evacuation routes. These calculations are highly computational intensive. Extra computational power will be provided by local banks, schools, companies, based on a series of policies and agreements.**

a) **Will the facility of running real time simulations would be useful for the decision making process?**
b) **Would such a timely provision (more exact and accurate information about the situation of the building) be of critical importance?**

c) **Could this lead to a safer way of evacuating a building (in terms of operating units and occupiers)?**

d) **Do you think that the approach as a whole will enhance your good practice in any other way? Specify.**

All four participants agreed that the ability of the G-AERM to run real time simulations is a very important feature and they were positive about all three parts of the question.

- **The proposed G-AERM is able to store all the process of the emergency operation and therefore this could be used to identify good and weak practice, to assess the process and it could also be used for future training of new staff. Do you consider these functions as useful and helpful to further improve your performance or avoid future mistakes?**

All four participants found this ability of the G-AERM very useful for training purposes. They highlighted that lessons learned from past events are a very useful resource in improving performance and training new members of staff.

- **According to your opinion is the proposed model able to provide you with more space to achieve your goal and improve your performance?**

One participant considered that the conceptual G-AERM is able to provide more space, however its real-world application needs to be done in close collaboration with each individual department involved in emergency response operations. Two of the four participants answered positively to this question as the G-AERM supports collaboration, which is a key to emergency response operations. The fourth participant stated that it is difficult to be sure as she would like to see the real-world application in working order.

- **Do you ultimately think that this model will assist stakeholders involved in making more informed decisions in a distributed, collaborative and cooperative manner towards the planning, control and management of emergency response operations?**

Three of the four participants said that the G-AERM will assist stakeholders in making far more informed decisions in a distributed and collaborative manner. The fourth participant pointed out that she could not be sure about it.

- **Could you please express your opinion of the proposal as an entity?**

All four participants stated that although some of the functions of the G-AERM are not easily applicable at the moment – as organisations do not have all data in digital formats and staff will need training to operate via the G-AERM – it seems to be a very informed and useful model that could improve emergency management stakeholders' performance during response operations.

- **Do you have any suggestions that could further improve the proposed G-AERM and therefore the way of managing emergency situations caused by natural disasters?**

All interview participants strongly believed that the model's support for collaboration and coordination between the authorities involved in emergency response operations is appropriate. A suggestion made by one participant was that the model must incorporate and not substitute human contact as it is important in emergency response operations. Two of the four participants said that although the model looks a way forward, its real-world application needs close collaboration with the relevant agencies to avoid legal conflicts. One participant said that research and development needs to be done on individual authorities in order to alternate their data so as to be ready for integration into the G-AERM's real-world applications.

8.4.1.2 Evaluation of G-AERM Technical Specification

This exercise evaluates whether Grid technology and, in particular, the proposed model architecture, is considered as an appropriate, effective and efficient means for a real-world application to be developed based on the G-AERM. Participants in the one-to-one structured interviews were all highly research active in the area of Grid technology and included the following:

- A Principal Researcher of Chimera, University of Essex;

- A Senior Lecturer, Institute for Research in Applicable Computing, University of Bedfordshire;
- Grid Programming Specialist, Italian Institute of Nuclear Physics (INFN).

The one-to-one interview questions used throughout the evaluation exercise were as follows. Free written transcriptions were made of the oral discussion and these are documented in Appendix V. The following paragraphs highlight the major responses:

- **The proposed solution stands as a Grid-Aware Emergency Response Model (G-AERM) that it is owned, managed and operated by a VO that is dynamically formed by emergency management and other directly involved authorities when a natural disaster occurs. This will improve the effectiveness and the efficiency in terms of controlling, coordinating and communicating the emergency management procedures and the relevant resource during emergency response operations in a distributed fashion (any time, any place, anywhere). Are you aware of any single IT system that accommodates all relevant to the Emergency Response activities as listed in table 1?**

All three participants pointed out that they are not aware of any single system that covers all requirements in the context of emergency response management. Two of them mentioned that there is a website called “myDisasterHelp” (available: https://www.disasterhelp.gov/suite/), which links to few top disasters stories and helps victims of a disaster to request information from US governmental bodies about what they need to do once a disaster has occurred. One of them stated that this website’s services are very different from those described and offered by the G-AERM. In particular, the participant stated that “myDisasterHelp” does not provide real-time communications and requires victims or other interested people to get in touch via phone or e-mail. Additionally, it is not a portal for emergency management stakeholders to communicate, collaborate and coordinate their activities during emergencies. Finally, the participant pointed out that Grid-based applications are in their infancy and therefore such a complex concept has yet not been fully envisioned or implemented.

- **Firstly, VO members will be required to access the Grid Services Portal Interface (GSPI) using the Secure Authorisation service. To gain access to the GSPI, perspective users need to apply for a certificate in order to be allowed to sign-on. This method allows them to utilise single sign-on (SSO) so they will not be required to multiple sign-on when accessing distributed services belonging to different owners. As can be seen in the Connectivity Layer, the Grid system utilises the Grid Security Infrastructure (GSI), which allows reliable and secure access to resources using Public Key Infrastructure (PKI), Secure Socket Layer (SSL) and X509 certificates. Based on their authentication, the VO member(s) will have access only to services, which are registered to their account. These services are located in the Grid Customised Applications Layer and are described in the Grid Services database system, which recalls resource authentication via the "set of policies" service. For example, an EM decision maker has the right to "access" a number of resources in order to "assess" them and "decide a relevant Emergency Response (ER) job plan". This is accessible by the ER operational units. When external expertise is required, the relevant leader is provided with the ability to amend or set up a policy of an appropriate level as required, in order for the invited external resource to join the VO environment. Similarly, leaders can amend or set up policies following the organisation hierarchy.**
    a) **Do the individual users or the VO require to apply for certificate in order to have secure access to the system?**
    b) **Will the GSI, by using PKI, SSL and X509 certificates, allow secure access to registered resources?**
    c) **Is the searching, amendment and cross-referencing of dispersed and heterogeneous documents – like a set of policies – with legislation and the bodies of law feasible through the Grid infrastructure as described?**
    d) **Is the above described approach technologically feasible?**

e) **Will the above described approach offer secure access to the GSPI?**

All three participants agreed that a single user or a VO member needs to apply for a certificate to have access to the G-AERM. In particular, they pointed out that as any user needs to be identified by an X509 certificate, they firstly need to apply for a Certifying Authority (CA) to be recognised by the model and by any other user or VO. To the second part of the question, all three participants were positive that the GSI, by using PKI, SSL and X509 certificates will allow secure access to the registered resources. Moreover, one pointed out that the PKI defines the architecture, the X509 defines the item used by the system in order to identify the user and, the SSL defines the communication protocol. In relation to whether the searching, amendment and cross-referencing of dispersed and heterogeneous documents with legislation and the bodies of law is feasible through the Grid infrastructure, one participant stated that he did not know. The other two said that based on Grid technology this should be possible and suggested that the problems that may occur during the implementation of real-world applications are related to whether governmental bodies will commit setting relevant policies in the speed that emergency management stakeholders may require. To the fourth part of the question, all three participants pointed out that the security adopted by the G-AERM is the industry standard. One participant further pointed out that this approach is currently working in different types of Grid applications and therefore it is a matter of applying good practice in the G-AERM's more complex environment. Finally, all three participants agreed that the G-AERM's approach can offer secure access to the GSPI.

- **This is located in the Grid Customised Applications Layer and its underlying specification relies on the Open Grid Services Infrastructure (OGSI), Open Grid Services Architecture (OGSA) and the Data, Access and Integration Services (DAIS) specification framework. In particular, a number of Application Programming Interfaces (APIs) have to be in place in order to provide access to the required proposed services like access to dispersed data sources, model sources, mining tools,**

collaborative environments, application software, computational power and instrumentation. These APIs can be programmed using various languages, such as C++, Java, Python and XML.

a) **Does the GSPI rely in OGSI, OGSA and DAIS in Grid infrastructures?**
b) **Could the use of APIs provide access to a number of collaborative tools as required services for the emergency response stakeholders?**
c) **Is this approach technologically correct and feasible by using current Grid technologies?**

Two of the participants pointed out that GSPI, as the user interface, relies on OGSI, OGSA and DAIS and works with standard technologies, like Java, C++, HTML and others. The third participant answered that he is not sure about this question; however, he pointed out that OGSI has been replaced by the WSRF. This was mentioned by two participants, who stated that although this replacement exists the proposed G-AERM architecture includes all practices delivered by the WSRF. Therefore, it may be worth considering replacing the OGSI with WSRF in order to adopt the latest technological developments. All three interview participants agreed that the use of APIs can provide access to a number of collaborative tools as required services for the emergency response stakeholders. They all agreed that the G-AERM architecture include relevant specifications.

APIs should represent the highest level of the infrastructure allowing the GSPI to easily execute complex operations hiding to the view programmer the complexity of the underlying Grid. One participant further mentioned that Python, Java or C++ is the standard practice and therefore, they can be used to develop and implement appropriate services. Finally, all three pointed out that the provided architecture diagram of the G-AERM is correct and technologically feasible. One participant found its real-world implementation quite challenging because of its scale.

- **It is expected that a number of resources will be available via the GSPI for decision makers to individually and/or collaboratively take them into**

consideration in order to produce an ER job plan together. In this respect, a Service Provider as a decision maker or else will need to register their resources/services to the resource directory (UDDI) and specify the policy in which the registered resource/service will be used by others. This will enable other parties to locate registered resources/services. In particular, to register resources/services, the Service Providers will be required to describe their resources/services using the Web Services Description Language (WSDL) in order to define how the service is to be used by others. Registered services/resources can be found using the Grid Services Broker, which includes registered services/resources metadata services (XML), which are connected to a Service Requestor using the Simple Object Access Protocol (SOAP). The Grid Services Broker is located in the Collective Layer.

a) **Can Service Providers register and make available their resources/services to a UDDI by describing them using WSDL?**
b) **Can registered services/resources be found using the Grid Services Broker, which lists registered services/resources metadata services (XML), which are connected to a Service Requestor using the SOAP?**

Two interview participants believe that the Service Providers can register and make available their resources/services to a UDDI by describing them using WSDL. In contrast with the third participant who pointed out that Web service-based Grid have not utilise UDDI as a discovery mechanism and it remains an open question whether UDDI is appropriate for this task, one of the first two – who has personal experience in developing such services for wireless networks and for financial decision making in Grid environments – said that this is working well. To the second part of the question all three participants pointed out that both Web Services and OGSA-DAI are suitable technologies for developing such services. In particular, one of them stated that a Grid Service Broker can find a resource through a UDDI registry, where a Service Provider has published its services. Once the Grid Service Broker identifies the required resource the connection between user and Service Provider service is done using the SOAP protocol.

- **On the other hand, an individual or a group of EM decision makers as Service Requestors will need to "access" a number of appropriate and relevant resources/services including data sources, model sources, data mining, decision support applications, processing power and other physical resources in order to "assess" the current situation and "decide the best possible ER job plan". The following lists the exact steps and the Gird technicalities required for an individual Service Requestor to request accessing to appropriate data/resource services using the OGSA-DAI specification framework, which operates under the Web Services Resource Framework (WSRF):**
  - **EM decision maker as a Service Requestor will need to request the Data Access and Integration Service Grid Register (DAISGR) for the source of data about a particular instance like X;**
  - **The DAISGR will return a handler to the Service Requestor;**
  - **The DAISGR will send a request to the Grid Data Services Factory (GDSF) to access the relevant data sets that are registered with it;**
  - **The GDSF will create a Grid Data Service (GDS) to manage access to relevant data sets;**
  - **The GDSF will return a handler of the GDS to the EM decision maker;**
  - **EM decision maker as a Service Requestor will perform the query to the respective GDS using a database language such as Structured Query Language (SQL);**
  - **The GDS will interact with the available dataset(s);**
  - **The GDS will return the query results in a XML format to the Service Requestor.**

    c) Is the above described list of functions technologically correct and feasible?

Two out of three participants strongly pointed out that these functions are correct and technologically feasible. The third participant mentioned that although he had not personal involvement recently, he believes that reading from literature it should be possible to develop such application.

- **Once a computational related job is issued to the Grid Job Manager via the "take action/run ER job" and the Grid Services Broker, the Grid Job Manager will need to check its scheduler and its job queues in order to discover the resource (for example, a cluster) and ultimately submit the ER job via the Grid Resource Allocator. Once the resource is found, the Grid Resource Allocator will send the job to the resource in order to execute the job. Initially, the job will be sent to the Master node, which will co-ordinate and spread sub-job tasks (as defined in the job plan) to the cooperating slave nodes. If a sub-job is interrupted for any reason, the Grid Manager will order to retry job completion for a predefined number of times. The Grid Monitor Services will alert the Grid Manager (for example, the cluster master node) in the event that the retry has been unsuccessful. In such case, the embedded Grid Services fault tolerance will request the Grid Manager to firstly save the partially completed work to a secondary storage and secondly, to alongside the Grid Resource Allocator, to identify and issue an alternative path to execute the remaining sub-jobs. Once the job is completed, the Monitoring Services, which are located at the Grid Job Manager will inform the Job Status Services, which will further notify the "Report" system activity, which will be stored to the data sources of the 'Collect' SSM activity. The Job Status Services will concurrently inform the Grid Job Manager that resources are available for future use via the Monitoring and Discovery Services. If a job has not been completed, has failed because no resources have been found available at the specified time, the Grid Controller will keep the job in the Monitor Queues that will attempt to identify alternate solutions for a predefined number of times. In the case that the process will be unsuccessful because of the expiration of the numbers of attempts or because of policies specified in the job plan, the Job Status Services will raise an "alert".**
    a) **Can the Grid Job Manager, through the Grid Resource Allocator submit a job to the available resources once these have been discovered?**

b) **Is the description of co-ordinating and spreading sub-job tasks by the Master node technologically correct?**

c) **Is the Grid Services fault tolerance service (as described above) a method to issue alternate paths for job execution?**

d) **Is the description as a whole of the Grid Middleware Resource Layer technologically correct and feasible with current technologies?**

All three participants strongly believe that the approach adopted for the G-AERM architecture is correct and feasible. According to one participant, all the adopted practices are supported by the literature, and another pointed out that he has personal experience in teaching and demonstrating all these services to postgraduate students. He also briefly described a couple of recently successful MSc projects, which refer to a graphical user interface that allows novice users to submit jobs to Condor pools using a Web interface.

- **This layer consists of the currently available EM distributed and potentially incompatible instrumentation/resources owned by different authorities, such as the Emergency Management Section, Civil Protection, Police, Fire and Rescue, and Health and Ambulance Services. Their instrumentation/resources include but are not limited to, VHF radios, mobile phones, landlines, vehicles (police, cars, ambulances, etc.), aircraft, satellites, computers, clusters, campus Grids, data, earth observation systems, weather stations, seismographs, geographical information systems, satellite phones, pagers, TV channels, military equipment, radio stations, data sources, model sources, data mining tools, etc. It is expected that human-related resources, such as operational units and external experts will be notified about their duties via the appropriate ICT equipment. These instrumentation/resources – depending on their physical nature – will be registered in the G-AERM's Data Grids, Computational Grids or Equipment Grids so they can be accessed accordingly. These will then feed the "collect data" SSM activity with appropriate information about the natural phenomenon and the**

current situation. These types of information are then stored in database or model-base management systems via the "store collected data" SSM activity. This activity functions as the gateway for the OGSI, OGSA-DAI Services Specification and the Grid Services Broker to locate and make instrumentation/resources available to the decision makers via the "access/assess data" SSM activity in order to "decide ER job plan".

a) **Can the instrumentation/resources described above be registered in the G-AERM's Data Grids, Computational Grids or Equipment Grids so they can be requested and accessed accordingly?**

b) **Is it feasible for the OGSI, OGSA-DAI Services Specification and the Grid Services Broker (as described above) to locate and make instrumentation/ resources available to the decision makers via the "access/assess data" SSM activity in order to "decide ER job plan"?**

All three participants strongly believed that the above functions of the G-AERM are correct and technologically feasible. One of them, who has worked with both data and computational Grids said that 'they are working fine'. With regard to equipment Grids he has not a personal experience but said that there is literature review supporting such implementations.

- **Overall, do you believe that the G-AERM architecture that is provided and described by the study, if followed (applied) could produce a real-world working version of the G-AERM? In other worlds, is the whole description of the G-AERM technically correct and feasible?**

All three participants strongly believe that although the scale of the G-AERM is challenging, the proposed model architecture and description as a whole are correct and technically feasible and could lead to real-world applications.

- **Do you ultimately think that the G-AERM will assist stakeholders involved in making more informed decisions (by providing them with a wider range of heterogeneous and dispersed options to choose from –**

enlarging the search space – in a distributed, collaborative and cooperative manner towards the planning, control and management of emergency response operations, if compared with current ICT in use?

All three participants believe that the proposed G-AERM will enable emergency management stakeholders to have a far wider range of options to choose from in a far quicker way, which will eventually lead to a more informed decision.

- **Could you please express your opinion of the proposal as an entity?**

All three participants were positive in relation to the G-AERM as an entity. One of them pointed out that it has obvious value to the emergency response stakeholders. Another participant strongly believed that having access to real-time data from a number of places is essential. Further to that, the aforementioned participant had some concerns about potential performance issues where Web services are being employed. The third participant pointed out that the G-AERM is clearly a far more effective and efficient way compared to current practices. He continued by saying that the G-AERM has envisioned "a bag" of highly valuable features and it seems to be a complete approach. Two of them recommended approaching emergency planning services and the National e-Science Centre (NESC) or other funding bodies to investigate potential funding and collaboration opportunities.

- **Do you have any suggestions that could further improve the proposed G-AERM and therefore the way of managing emergency situations caused by natural disasters?**

Two participants suggested that training of relevant people is important for real-world applications of the G-AERM. One of them in particular said that G-AERM's users will need a lot of training in various simulation scenarios in order to perform their tasks in a productive way and ultimately exceed their current productivity levels so they could use G-AERM in its full potential. Further to that one participant recommended that there is the need somewhere in the research to clearly state and emphasise that the G-AERM focuses on addressing current limitations of ICT-based sources only and its purpose is not to appreciate the need for integrating and providing paper based sources or manual processes via the Grid.

8.4.2 Analysis of Finding of the Evaluation Exercises

Following the evaluation studies, the proposed G-AERM has been assessed in terms of its effectiveness and efficiency, in relation to both its conceptual and technological aspects. This section is concerned with the analysis of the findings deriving from the evaluation exercises of the G-AERM, in terms of its Strengths, Weaknesses, Opportunities and Threats (SWOT).

Findings from the evaluation exercise with emergency management stakeholders clearly demonstrate that the proposed G-AERM overcomes all the ICT limitations they currently face, adopts the processes of emergency response management and addresses all the set of requirements drawn by the study. All participants in this evaluation exercise were fully satisfied with the proposed G-AERM and that its capacity to clearly stand and strengthen their good practice during emergency response operations in a far more collaborative, effective and efficient manner if a G-AERM application was available.

In particular, all interview participants stated that the strength of the G-AERM is that it is the first single IT system that accommodates all the activities related to emergency response management in both conceptual and technological terms. Further to this, they also felt that the G-AERM is appropriately designed for planning, controlling, coordinating, collaborating and communicating actions between emergency management stakeholders. Grid technology experts highly supported that the use of Grid technology components in the G-AERM architecture is correct and technologically feasible, that individual Grid components used in the model architecture can work in the way as they are built together and the architecture provided as a whole can be used towards the development of relevant real-world applications.

Another very important strength of the G-AERM is that interview participants supported the view that the model, in the form of a VO is able to support the collaborative and dynamic provision and use of all currently available resources and instrumentation that can be accessed via APIs – that can be developed using Java, C++ or Python programming languages - to dynamically integrate and seamlessly collect and store all data relevant to the situation concerned offering the ability to analyse and utilise data and instrumentation from multiple dispersed and heterogeneous resources. In turn, VO members would be have a wider range of sources to work with which will offer emergency response stakeholders with far more options to choose from so a better solution could be encountered from the enlarged search space. Grid technology experts found that the security adopted is in industry standard. VO members through the GSPI's embedded industry standard security mechanisms like X.509 and CAs will be allowed to securely access this enlarged data and instrumentation resource provision – via OGSA and DAIS - towards the collaborative and collective decision making process in a far more effective and efficient manner.

In line with the conceptual SSM model, the capabilities of the G-AERM as provided by OGSA, DAI and WSRF services will allow emergency response stakeholders to dynamically keep informed and be alerted about a given situation. Similarly, emergency response stakeholders can dynamically keep informed and alerted of available relevant registered and authorised resources and instrumentation in real time so they can take them into consideration when planning an emergency response and therefore issue job plans in a far more effective and efficient manner. These points were found very important by emergency management stakeholders and clearly demonstrate strengths of the G-AERM.

Other strengths include the real time information and feedback about the operation, the ability of the G-AERM to run simulations and requests about alterations of policies and the transmission of objective information through written forms of communication. Further to these, another strength of the model is that it allows emergency managers to be located in the areas that are in need and at the same time to have access to the system and be able to manage the whole operation.

WSRF and GSB alongside with GRSA and GJM services will allow computer based resources to undertake a number of dynamic and automated tasks collaboratively such as what-if scenarios and running complex and highly intensive simulations. Embedded grid fault tolerance services and job schedulers will also allow reallocation of jobs to other resources if original resource(s) will become compromised so the scheduled job will continue according to the plan. Finally, the expansion of there search space will result to more informed decisions and overall the G-AERM is able to serve as a more effective and efficient way of managing emergencies.

Grid technology experts felt that a weakness of the G-AERM is that it uses OGSI as this has been lately replaced by WSRF. In response to this point, the G-AERM architecture has been refined to reflect the point made and ultimately satisfy their suggestion. These refined versions have been further shown to one of the grid expert participants who raised the suggestion in the first instance and he was now fully satisfied with refinements made by the author.

Other weaknesses include that not all means of communication, like VHF, are integrated with Grid environment yet and that not all data used in emergency response operation is yet digitised. Additionally, the installation of cameras for real time images in areas with difficult access (i.e. forests, sea) will be a challenge. Emergency managers felt that physical meetings between them during decision making should not be cancelled or totally replaced by virtual ones. Further to this, they stated that the on demand alteration of governmental policies should be in line with government's procedures in order to be legal.

Some of the opportunities for both developers and users of the real world applications of the G-AERM derived from the evaluation include the facts that its scale is challenging and Grid-based applications are in their infancy and such a complex concept has yet not been fully envisioned or implemented. Additionally, the building of Grid infrastructures in relevant bodies in order to accommodate G-AERM will be an opportunity for development and for this reason digitalisation of data currently handled by relevant bodies needs to take place. These real world manifestations need be dove in close collaboration with governmental bodies in order legal issues to be resolved.

There is the need for training of people that will operate the G-AERM as they will be multidisciplinary users and this offers the opportunity for relevant staff to be more educated on how to handle emergency situations. Once the G-AERM will be used it will offer material for training and exercises from past event. Overall, based on the evaluation exercises, the G-AERM includes a number of activities that offer the opportunity to minimise mistakes, make more informed decisions and strengthen and extend current good practice. For all these functions to run smoothly and according to the bodies of law, the codes of practice, the quality of service, the ethicality and other issues including environmental and humanitarian concerns, a set of pre-defined and/or dynamically generated policies as required appropriately will be embedded within the VO. In terms of technology to support these functions, WSRF and OGSA-DAI services will allow relevant stakeholders to upload, register so these can be discovered when required.

Finally, according to the people that took place to the evaluation of the G-AERM, there are some threats that need to be taken into consideration. These include the facts that there is the potential of some performance issues where Web services are being employed and that infrastructure supporting real world applications need to be kept up-to-date with new technological developments. In addition to these, as a threat is considered the commitment of governmental bodies to set relevant policies in the speed that emergency managers may require and the overall political decisions of governments towards real world manifestations. Finally, there is the need for clear and detailed policies for sharing information between relevant bodies in order misunderstandings and legal issues to be avoided.

Table 8.1 is a representation of the Strengths, Weaknesses, Opportunities and Threats of the G-AERM based on both evaluation exercises.

Table: 8.1: SWOT Analysis of the Evaluation Exercises of the G-AERM

Strengths	**Weaknesses**
• First time that a single model accommodating all processes required to manage emergency response operations	• OGSI has been replaced by WSRF
• Designed for planning, controlling, coordinating, collaborating and communicating actions between emergency management stakeholders	• Means of communication (like VHF) are not yet integrated with Grid environment
• Architecture diagram is correct and technologically feasible	• Cancellation of physical meeting between emergency management stakeholders during decision making may become a norm
• Support for creating and sustaining VOs	• On demand alteration of governmental policies should be in line with government's procedures
• Support for emergency managers to collaborate remotely	• Installation of cameras for real time images in areas with difficult access (i.e. forests, sea)
• Tools supporting objective information sharing between involved bodies	• Not all data is currently in digital format
• Use of APIs can provide remote access to a number of collaborative tools	
• Industry secuity standards adopted	
• GSI, by using PKI, SSL and X509 certificates allows secure access to the registered resources	
• Service Providers can register and make available their resources/services to a UDDI by using the latest developments in Web Services	
• Service Seekers can be made aware of the most relevant and available resources/services by using the latest developments in Grid Services	
• Automatic expert identification	
• Support to run simulations towards decision making	
• Expansion of decision making search space	
• Time efficient (especially in areas with difficult access)	
• Real time information and feedback	
• Error handling leading to fewer erroneous decisions	
• Enabling more informed decisions	
• On demand alteration of policies	
• Support for fault tolerance (Grid-FT)	
• Web Services and OGSA-DAI are suitable technologies for developing proposed services	
• Overcomes all current ICT limitations	
Opportunities	**Threats**
• Grid-based applications are in their infancy and such a complex concept that has yet not been implemented will advance parties involved when developing applications	• Will governmental bodies commit setting relevant policies in the speed that emergency management stakeholders may require?
• Digitalisation of data currently handled by relevant bodies	• Potential performance issues where Web Services are being employed
• Scale of G-AERM will challenge and advance collaborative practice	• Infrastructure supporting real world applications need to be kept up-to-date with new technological developments
• Collaborative practice between governmental bodies to enable G-AERM application development	• Availability of operational unit to provide the system with feedback during operation
• Development of pre-defined and/or dynamically generated policies as required	• Political decisions of governments towards real world manifestations
• Building of Grid infrastructure in relevant bodies in order to accommodate G-AERM	• Policies for sharing information between relevant bodies
• Relevant people will learn more as they will receive training of how to operate a G-AERM based application	
• G-AERM and its application may be utilised as a method to train staff using real world recorded past cases	
• Number of supporting activities that strengthen and extend current good practice	

In conclusion, it is appropriate to suggest that the overall aim of the research study to develop a Grid-Aware Emergency Response Model (G-AERM) serving emergency management stakeholders in monitoring, planning, controlling and managing actions within an emergency situation caused by natural disasters in a far more informed, effective and efficient manner has been fully supported and evidently met in the light of the evaluation studies with experts in the field.

8.5 Implications of Embedding the G-AERM into the Real World

One of the major implications in using Grid technologies as a vehicle to assist emergency management decision makers is the ability to enlarge the actual search space boundaries within the term of "problem space" as described by Simon (1977). The problem space represents a boundary of an identified problem and contains all possible solutions to that problem, such as optimal, excellent, very good, acceptable, bad solutions and so on. By searching in a narrow space, where the emergency management decision maker do not have full access of the current situation will most likely lead to not choose an optimal solution. It is therefore, believed that the incorporation of the activities as illustrated in the SSM conceptual Emergency Response Model (ERM) with Grid technologies will enable:

- Various individuals and/or collective resources to make a more than currently informed decision by increasing the opportunities for a better solution to be encountered as, it will allow them to know more about the concerned situation by:
    - running complex and intensive what if scenarios and/or other problem-solving scenarios in parallel;

  but most importantly, by:
    - providing them with seamless integrated access to assess what is currently available and relevant from multiple dispersed resources;
    - allowing them to work in a collaborative manner.

Clearly the Grid potentially increases the size and complexity of the problem spaces that can realistically be addressed not only by emergency management scenarios, but by all types of interdisciplinary type of enquiries, which an organisation may wish to address.

Another very important implication of embedding the G-AERM in the real world is that there is the need for some of the ICT methods currently used by emergency management stakeholders to be able to work in a Grid environment. Apparently, the G-AERM requires the use of electronic based resources to take full advantage of the proposed method. That is to say, it is expected stakeholders will have databases holding information about their physical resources, and that they are willing to share them with others across the Grid infrastructure. It is important to note that the proposed G-AERM assumes that the emergency management authorities have access to a number of instruments and that any related data needed to be accessed and assessed shall be stored in electronic form. Currently there is data that is paper based, such as maps, materials specifications, building, engineering plans and town plans. The study does not aim to be a commercial product therefore, it should be considered as the underlying concept for future manifestations. There is much activity in developing relevant middleware and this is considered as achievable by Grid technology experts. Therefore, authorities involved will be able to utilise existing resources and infrastructure towards the creation of the G-AERM.

However, this implementation will create the need for users' training in order to be able to use the real world application in its full potential. Emergency managers, authorities' leaders and operational units need to be trained using simulation exercises to be familiar and feel confident to operate in using the G-AERM. At the same time, G-AERM has the ability to keep a record of its function, during both training and real world operations. This function therefore offers emergency management stakeholders the opportunity to identify good and bad practices after the completion of the operation, to use them for further training purposes and to amend emergency plans, laws and other relevant documentation in a governmental level.

The research has not taken into consideration such attributes in order to produce the G-AERM, as the focus was to propose a concept that could further support emergency management authorities in achieving a more effective and efficient management of natural disasters and not to create a real world application. However, this is considered essential by emergency management stakeholders if G-AERM is to be adopted in real world practice. As mentioned during the evaluation exercise, there is the need for the G-AERM to be compatible with the legal framework of the country of its implementation. That is to say, during the creation of real world applications emergency management authorities need to work together with the central government of the country to address and resolve any legal conflicts.

8.6 Summary

This chapter presented the evaluation of the G-AERM in terms of its effectiveness and efficiency, as these identified by SSM's epistemology. It presented the one-to-one interview exercise participants, the questions used, the answers provided and the SWOT analysis of both the concept and the proposed technological solution for the G-AERM. Further to this the chapter has presented the refined and validated versions of the grid components used in and the detailed G-AERM in the light of a minor suggestion made by two grid experts during the evaluation exercise. The next chapter concludes the research; it summarises the thesis, presents limitations of the research and concludes by making suggestions for further work.

Chapter 9 Conclusions and Recommendations

9.1 Introduction

Chapter 9 is concerned with the conclusions of the research, which studied the feasibility and applicability of Grid technology to the area of emergency management. It presents the research process and highlights the main conclusions of this thesis by summarising the achievements of the undertaken research. Finally it critically discusses the research limitations and makes recommendations for further work and research.

9.2 Summary of the Research

The aim of the research was to study the feasibility and applicability of Grid technology to emergency management such that stakeholders can monitor, plan, control and manage actions within an emergency situation caused by natural disasters in a more informed way. This aim has been met following a series of methods, which have been embedded to the holistic research methodology and they have led to the successful development of an integrated approach for the problem area, which has been positively evaluated.

A literature review of natural disasters was carried out to gain an essential understanding about the subject. It revealed that natural phenomena are essential and unavoidable planetary actions, which when occurring in extreme forms and in areas inhabited by people may cause disastrous results to the human life, property and the environment. It was also found that the number of losses caused by the occurrence of such events is increasing during the last decades. The literature review also suggested that humans have formed various emergency management bodies, in local, national and international levels, in order to manage the consequences of the occurrence of natural disasters. In particular, such bodies are concerned with the mitigation, preparedness, response and recovery from natural disasters.

The research was focussed on emergency response, as it is considered a very important phase of the management cycle. Emergency response takes place immediately after the occurrence of an extreme natural phenomenon and it may continue for minutes, days or months, depending on the scale of the disaster. During emergency response many different professionals, from different disciplines and with different expertise need to collaborate towards decision making with overall aim of managing the disaster.

Descriptive case studies from two countries based on two member states of the European Union were employed to further investigate the ways emergency management is organised. The emergency management bodies of each country have been investigated, along with organisational procedures, emergency plans, and resources used during the response phase. One-to-one structure interviews with emergency management stakeholders – representatives of the two aforementioned countries – revealed the ways stakeholders operate during the phase of response, how they organise the operations, how they collect, access and asses data towards decisions making and how they communicate decisions of action. These primary and secondary research findings suggested that there was still room for improving the collaboration, coordination and communication of the relevant stakeholders involved in emergency response operations when the occurrence of a natural catastrophic phenomenon causes an emergency or a disaster, by focusing on ICT limitations.

A further review of existing literature suggested that Soft Systems Methodology (SSM) was the most appropriate research methodology to tackle the research problem. An extensive review of different approaches, with particular reference to the “hard” and “soft” ones concluded that the “soft” approach is considered as the most appropriate one for the exploration, identification and demonstration of the conflicts and problems, which emergency management stakeholders face during the decision-making and action process of the response operations. SSM investigates the research problem with main focus on the human multi-perspective views and is the appropriate methodology to address messy problematic environments. Employment of SSM has assisted in further exploring ICT limitations, including information gaps, communication breakdowns and hierarchical complexity during response operations.

Further employment of SSM epistemology led to the formulation of a conceptual model with particular reference to emergency response management operations for natural disasters. The Emergency Response Model (ERM) has been compared with perceived reality and the findings revealed that although the activities of the model existed in the real world, the forms in which they existed and the fact that they did not exist in a single model or system caused problems during the response operations. Clearly, the approach of the ERM to facilitate emergency management stakeholders with an up-to-date picture of what is currently available about the situation concerned will increase possibilities for a better solution to be encountered. The forms in which the model's activities appeared and operate could support the distributed nature of emergency response management to further support current practice, in terms of effectiveness and efficiency. The study illustrated a proposed concept of how to accommodate all the processes and needs of decision makers, operational units and instrumentation during emergency response operations in a single model.

However, it was found that there was still the need for incorporating ERM with an appropriate computerised infrastructure, able to accommodate the collaborative nature of the defined emergency response management procedures in such a way that will overcome current ICT limitations, according to the above-mentioned demands. Therefore, it had to be a technology capable of incorporating different types of data, software and hardware; capable of running parallel and highly demanding jobs; and to work in a timely and dynamic fashion to support the collaborative nature of stakeholders to plan, control, coordinate and communicate activities related to the emergency response operations.

A detailed description of Grid technology and the evolving standards as the latest advance to support collaboration in a distributed environment has been presented. Relevant discussion drawn from one-to-one interviews with Grid technology experts and findings from primary and secondary research works concluded that it is possible and useful to deploy Grid technology as the method to serve the purpose of managing the response operations in emergency situations caused by natural disasters in an improved way.

To achieve this, Grid technology has been incorporated to the proposed ERM in order to produce a complete solution for managing emergency response operations in an effective and efficient way. Earlier literature review with regard to "hard" and "soft" methodological approaches concluded that the "hard" approach is considered as the most appropriate one for the production of a set of real-world technical requirements. Therefore, the linking of SSM with ISDMs was used as the approach to bridge the "soft" ERM with the "hard" technical solution. The method involved the formulation of a set of guidelines for producing real-world technical requirements by identifying the user and the activities to be supported in the form of a process flow chart. These have been further elaborated with the aim of enriching findings towards the further development of the conceptual ERM resulting from the SSM enquiry with Grid technology to produce the architecture for the Grid-Aware Emergency Response Model (G-AERM) for managing natural disasters. The G-AERM aims to serve as the framework for the development of real-world applications, as a method to support emergency response stakeholders to work remotely and collaboratively in order to monitor, plan, control, coordinate and communicate relevant actions in a more effective and efficient way.

The evaluation exercise was concerned with the evaluation of both the conceptual and the technological aspects of the G-AERM, in terms of its effectiveness and efficiency. The application of the evaluation method consisted of the creation and conduction of a series of one-to-one structured interviews with emergency management stakeholders and Grid technology experts. Outcomes of the evaluation exercise with emergency management stakeholders suggested that the use of G-AERM would be a more effective and efficient means for planning, controlling, co-ordinating, collaborating and communicating actions during emergency response operations when a natural disaster occurs. Outcomes of the evaluation exercise with Grid technology experts suggested that the use and the arrangement of Grid technology components in the G-AERM architecture are correct and technologically feasible both as parts and as a whole. Finally, Grid technology participants fully supported the view that the G-AERM as a whole can be used towards the development of relevant real-world applications.

9.3 Conclusions

Based on the findings of the research, the following conclusions can be drawn:

- Emergency management organisations need to collaborate and work closely with the central government, other neighbouring local authorities, armed forces, utility companies and local industry, as well as with volunteers and voluntary bodies, to ensure that the emergency operations are as effective and efficient as possible to respond to a natural disaster. Their coordinated control and decision-making actions take place within a distributed working environment.

- The produced Emergency Response Model (ERM) has been compared with perceived reality and validated by emergency management stakeholders. Findings revealed that although the activities of the proposed model existed in the real world, the forms in which they existed and the fact that they did not exist in a single model – like the proposed ERM – caused problems during the response operations. The proposed ERM demonstrated how to logically arrange and accommodate the distributed nature of all the processes and needs of decision makers, operational units and instrumentation during emergency response operations in a single model.

- Emergency management stakeholders need to work in a collaborative manner to make informed decisions based on multiple dispersed and heterogeneous resources in order to increase their understanding about the situation by knowing as much as possible in relation to what is available at a given time. Findings demonstrated that current ICT in use during emergency response operations are both ineffective and inefficient. Key limitations include: gathering of stakeholders to a centralised place is time consuming; centralised store of important information; gathering of stakeholders to a centralised place limits access to individuals' centralised resources/data; non-timely exact information about the phenomenon; not exact information about available resources; no real-time pictures; failing of telephone networks; overloaded telephone networks; possible computer network failure; and incompatibility of computerised means of communication.

- The production of the Grid-Aware Emergency Response Model (G-AERM) demonstrated that the approach of incorporating the ERM with Grid technology is technologically feasible and appropriate. Most importantly, the approach adopted in the G-AERM architecture allowed stakeholders as parts of a wider VO to identify and select choices from a far larger range of resources available. Clearly, this will increase the possibilities for decision makers to take and issue more informed decisions of a collaborative nature towards the accomplishment of issued tasks in a far more effective and efficient way. Findings clearly demonstrated that the proposed G-AERM overcomes all the ICT limitations they currently face, adopts the processes of emergency response management and addresses all the set of requirements drawn by the study. Findings also fully supported that the architecture provided as a whole can be used towards the development of relevant real-world applications.

- The development of real-world implementations based on the G-AERM will have implications in the local and wider community. For example, these may expose segmented organisations to identify previously regarded intractable problems, such as the need to share their data and resources with others. It will also lead to the need for users' training in order to take advantage of G-AERM full potential.

9.4 Limitations of the Research

This section makes a critical appraisal of the research and identifies the aspects that would have done it more complete. These limitations include:

- There were efforts to include more case studies in the research. Contacts made with five countries of the European Union however, the selection of the case studies was limited to two of them. Two other countries did not wish to participate. Italy as the remaining country provided with relevant documentation that was written in Italian. As there were no resources to translate documentation, Italy was not included in the study.

- There were efforts to involve five emergency management stakeholders and four Grid technology experts as participants to the evaluation exercise. However, it was limited in seven participants in total. This included four emergency management stakeholders (two from England and two from Greece) evaluating the conceptual basis of the ERM and the G-AERM. It also involved three Grid technology experts evaluating the G-AERM in terms of its proposed architecture. It would have been beneficial for the output of the study if both the ERM and G-AERM have been evaluated with a larger group of participants. If participants from different hierarchical levels and from different areas have participated to the evaluation exercise the output of the research and the evaluation of the proposed solution would have been more informed.

- The initial plan for the evaluation – proposed by the supervisors – was to run a workshop, inviting emergency management stakeholders and Grid technology experts to assess the proposed solution to the problem area in an interactive process. However, evaluation participants and in particular emergency management stakeholders could not participate to the workshop as time was limited for them. The adoption of this method would have made even more limited the number of participants of the evaluation exercise and the overall evaluation of the G-AERM. Based on that, it has been decided to follow the one-to-one structured interview method to execute this task.

- Although the focus of this research was not to create a real world implementation, but to propose the concept and the most appropriate technology for a single model to accommodate the activities of emergency response management operations, the output of the study would have been more informed if a small-scale prototype of the G-AERM had been produced and thereafter evaluated. This is also supported by SSM's epistemology, which suggests that the evaluation of the proposed solution has to be done in terms of the three Es – effectiveness, efficiency and efficacy. However, the G-AERM has been evaluated in terms of its effectiveness and efficiency only, as efficacy is related to whether the real world application is working. It is worth noting that the author did not have the appropriate technical background to do this implementation and she also did not have access to a Grid infrastructure. Finally emergency response management resources were not available for use due to their confidentiality.

9.5 Recommendations for Further Work and Research

The research has revealed a number of limitations that could lead in undertaking further work in the area. It is also recommended that:

- Digitisation of paper-based material and applicable manual processes residing in authorities involved in emergency management decisions and operations could be pursued so they can be incorporated to G-AERM's real world applications. For example, digitisation of building technical drawings and their availability through the G-AERM infrastructure may increase the value of the proposed model.

- Further evaluation to assess the suitability of the G-AERM with regard to man-made disasters and industrial accidents could be also pursued. Along with natural disasters, these two categories complete the disasters that the European Union considers as threats for its member states. If the adoption of the G-AERM to the response to all three categories is possible it could offer emergency management stakeholders a complete effective and efficient solution during emergency response operations.

The research has also revealed a number of areas for further research, which include the following:

- Explore the social networking implications caused by VO interactions with particular reference to the use of G-AERM real world applications. It may also be of value to study whether the use of such an application could increase or decrease the current high level of stress of stakeholders occurring during an emergency response operation. In turn, investigation of what is required from a sociological point of view could further improve G-AERM value.

- Investigate and subsequently refine ERM's individual activities and their inter-relationships with particular reference to specific natural disaster instances such as floods, fires, earthquakes or tidal waves. Such investigations could lead to more informed ERM sub-parts, which in turn could lead to a further refined version of the ERM as a whole. Refined and specific versions of the ERM should also lead to a more effective and efficient G-AERM application.

- Investigation of what may constitute a common terminology for various emergency management stakeholders could lead to more effective and efficient synergies between VO members. This will also inform taxonomy and ontology definitions required for the ERM and for participated VO members. Such ontology definitions would be of high value in order for real-world applications to be developed.

- Usability studies could also take place. These studies should improve the way in which emergency management stakeholders – as VO members – will interact with each other, either as individuals or teams via the G-AERM application. The usability studies are considered a critical part for the successful operation of the G-AERM application. Finally, comparative studies between current ICT in use with a developed G-AERM real-world application could take place to realistically measure proposed model's performance.

9.6 Summary

Overall, the research has investigated the areas of natural disasters and emergency management, with particular interest to the conflicts and ICT limitations, which emergency management stakeholders face during emergency response operations. To overcome such problems, it has been proposed the integration of Grid technology in the field of emergency response management, as the most appropriate way to address the set of problems, requirements and issues that emergency management stakeholders face as these came out from literature review, case studies, and structured interviews. This has been done via the development and successful evaluation of the G-AERM for natural disasters. The produced G-AERM for natural disasters supports the collaborative and dynamic provision of all available resources and instrumentation towards the accomplishments of emergency response tasks. This has been achieved by collecting, storing and integrating data from multiple distributed and heterogeneous ICT sources in a seamless and dynamic way. The approach adopted in the G-AERM architecture allowed stakeholders to identify and select choices from a far larger range of resources available. In turn, this may increase the possibilities for emergency management decision makers to take and issue more informed decisions of a collaborative nature towards the accomplishment of issued tasks in a far more effective and efficient way.

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Appendix I List of Publications Arising from the Research

Asimakopoulou, E Anumba, C J and Bouchlaghem, N M (2207) Towards a Grid-Aware Emergency Response Model for Natural Disasters in Bessis, N (ed) Grid Technology for Maximizing Collaborative Decision Management and Support: Advancing Effective Virtual Organizations, IGI Publishing (under review).

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