The Development and Evaluation of a Virtual Simulation Tool for Testing Emergency Response Planning Strategies within the UK Gas Industry

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Abstract

Third party damage from activities such as work carried out by contractors' poses risks to gas pipelines. Within the UK, emergency plans are drawn up in an attempt to mitigate the significant consequences of any pipeline failure. The Control of Major Accident Hazards 1999 and the Pipeline Safety Regulations 1996 place legislative requirements on UK gas infrastructure providers, to regularly test emergency plans with simulation exercises. The exercises are intended to support the preparation of responders for dealing with incidents of failure. Software simulation is not currently utilised to facilitate the testing of emergency response plans in the UK gas pipeline industry. This project serves to evaluate the user acceptance of a software simulation prototype to enable the testing of emergency response planning strategies in the UK gas industry.

Current emergency planning legislation and strategies applied to satisfy legislation within the UK gas industry are reviewed. The adoption and application of software simulation for the development of applied skill in other industries is examined, to determine the potential for use in testing emergency response planning for gas incidents. The Technology Acceptance Model (TAM) is the theoretical framework that underpins the study of user acceptance, of a software simulation prototype designed for running exercises to test emergency response plans.

A case study evaluation of the user acceptance of the prototype, by representatives experienced in testing emergency response planning strategies in the gas industry, is presented. The participants in this case study are drawn from the Police, Fire and Rescue Service, Local Authority and Gas infrastructure

provider, that perform a range of job roles operating at Operational, Tactical and Strategical levels. The research findings demonstrate that the participants perceive software simulation of emergency response planning processes for gas incidents to be beneficial. The TAM claims that if users perceive a system to be useful they are likely to adopt that system. Furthermore if users don’t perceive a system to be easy to use, according to the TAM, they will still adopt it after the correct training has been provided. Users would be most likely to adopt and use the software to facilitate emergency response planning exercises, if the correct training is provided. Software simulation offers great potential for the testing of emergency plans, it provides a controlled environment where decisions and responses can be audited and mistakes can be made without serious consequence. Software simulation has been shown to enhance, rather than replace, existing emergency response planning processes.

Contents

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The late Graham Kimpton who tirelessly responded to my demands for support with improving the model used within the software simulation developed within this research.

My husband, I could not have completed this work without his ongoing support.

Author's Personal Statement

This personal statement outlines the role of the researcher, background and their position related to other organisations. Upon gaining a BSc in Computing, I proceeded to work in the Software Industry as both a Software Developer and Systems Architect on software development projects. The first half of my career in software development involved creating software solutions for Architects and the Construction industry. More recently my career has focused upon developing web applications. As a result I have gained knowledge and experience in the use of a range of technologies and software development techniques.

Whilst applying emerging technologies to a variety of applications, I developed an interest in understanding why certain technologies were preferred by users over others for different tasks. This interest was developed further whilst studying for an MA in Media and Cultural studies part-time. These studies allowed me to explore the impact of popular culture on human actions. In particular I studied the way users utilised new media technologies such as virtual spaces for cultural activities like visiting art galleries or concerts. My final research project focused on these topics and introduced me to academic research from a new perspective.

Upon completing the MA I sought to further develop my research career and began seeking potential research projects for studying the acceptance and use of technology in new domains. I was introduced to a potential PhD research role in a collaborative project with Northern Gas Networks and Northumbria University. Northern Gas Networks were interested in the possibility of applying software automation to enable the testing and training of emergency response planning processes. The project offered an exciting new opportunity to explore the possibilities software automation could bring to the existing process of emergency response management. It also offered the opportunity to gain an in-depth knowledge into user acceptance theory. This thesis serves to document the research journey taken and the contribution of the project.

Author's Declaration

I declare that the work contained in this thesis has not been submitted for any other award and that it is all my own work. I also confirm that this work fully acknowledges my opinions, ideas and contributions from the work of others. The work was done in collaboration with Northern Gas Networks.

Any ethical clearance for the research presented in this thesis has been approved. Approval was sought and granted by the School Ethics Committee on 31st January 2012.

I declare that the Word Count of this Thesis is 62,324 words

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Chapter 1 Introduction

This chapter presents an introduction to the background of the research. The aims and objectives of the research are defined. The contribution to knowledge the study presents is outlined. The organisation of the thesis and the journey it takes in explaining the process of achieving the contribution to knowledge is presented.

1.1 Research Background

Large scale incidents requiring a response from multiple emergency response organisations call for careful planning and organisation. UK legislation necessitates an organisation considered to be at risk of incidents requiring a multiple agency response, to plan and prepare for such incidents (Great Britain: Control of Major Accident Hazards 1999; Great Britain: Pipeline Safety Regulations 1996). In the gas industry, gas network providers supply the infrastructure that transports and stores gas. Gas network providers are legally bound to comply with UK legislation with regards to planning and preparing for major incidents. The legislation places a legal requirement on organisations to test and review plans once every three years. Exercises to test the plans are necessary and representatives of organisations likely to respond to an incident involving the gas network, are expected to attend and participate in the exercise. Methods currently used in the UK for testing emergency response planning strategies for high pressure gas pipelines do not utilise software technology in their facilitation. This research explains existing methods used for testing emergency response planning strategies and explores the possibility of using software technology for facilitating exercises to test plans.

1.1.1 Current Industry Safety Management Activities for Testing Emergency Plans

Tabletop role play is a method currently employed and commonly used for conducting emergency response strategy training exercises. This method involves gathering participants at a single location, around a table to perform a simulation of an exercise to test an emergency response plan. Exercises carried out to test and disseminate planning information, often require individuals to participate from geographically dispersed locations. Organising attendance of individuals from multiple organisations to exercises can be a logistical challenge. Cost, complexities, availability and geographical dispersion of personnel are all highlighted as problems with tabletop and live role play simulation exercises (McGrath et al., 2005; Campbell et al., 2008).

1.1.2 Software Simulation for Testing Emergency Plans

Software simulation offers great potential for the testing of emergency plans (Smith and Carter 2010; Tichon et al., 2003; Haller et al. 1999). The adoption and application of software simulation for the development of response and applied skills is well documented in other industries such as aviation, military, medicine and the emergency services (Grant and Meadows 2008; Macedonia, 2002; Crane et al. 2001; Huddlestone et al., 1999; Messina et al. 1997; Lampton et al., 1995). It provides a controlled environment where decisions and responses can be audited and mistakes can be made without serious consequence. Technology can allow exercises to be run simultaneously across multiple locations, providing opportunities for a wider range of participation.

The gas industry does not currently employ software simulation for training exercises required to satisfy Control of Major Accident Hazards 1999 (COMAH) and Pipeline Safety Regulations 1996 (PSR) legislation. An investigation into software simulation and the contribution it can bring to emergency response planning for major incidents is the basis of this thesis.

1.2 Research Aims and Objectives

The aim of this thesis is:

To evaluate the user acceptance of a virtual simulation prototype that serves to enable the testing of emergency response planning strategies in the UK gas industry;

Six research objectives support this aim, these are:

1. To examine and document current practice for emergency response planning exercises, for high pressure gas pipelines;

2. To investigate and review the application of software simulation as a tool for facilitating the testing and training of emergency response planning strategies;

3. Identify and review frameworks and qualitative methods in order to enable the development of a methodology for capturing, measuring and evaluating user acceptance of software simulated emergency response planning strategies;

4. To develop and refine a virtual simulation prototype with which to perform the user evaluation study;

5. To evaluate and compare the virtual simulation prototype with that of traditional methods for testing emergency response planning strategies;

6. To evaluate user acceptance of virtual simulation for testing emergency response planning strategies in the UK gas industry.

1.3 Contribution to Knowledge

The research provides two distinct components that contribute to knowledge, these are:

1. The evaluation of the user acceptance of a software application for performing gas infrastructure emergency response strategy testing

2. The development of a software application to enable the testing of emergency response plans in the UK gas industry

The use of software simulation to develop competencies in response and applied skill is well documented in other industries (Grant and Meadows 2008; Macedonia, 2002; Crane et al. 2001; Huddlestone et al., 1999; Messina et al. 1997; Lampton et al., 1995;). In the UK gas industry, software simulation offers a novel approach to conducting exercises for testing emergency response plans. The knowledge developed through prototyping and evaluating a software simulation for testing gas emergency plans, contributes to existing knowledge in a novel context.

Existing methods for conducting emergency response exercises to test plans are examined and reviewed. The process of developing a prototype to enable the testing of emergency response plans with responders from multiple agencies is described and discussed. The evaluation of the application of the prototype to develop response and applied skill and the results of that evaluation is documented.

1.4 Organisation of Thesis

The thesis is organised into ten chapters, the structure and content of the chapters are described in this section. Figure 1 shows the process model that maps out the organisation of the thesis and how it relates to the research objectives.

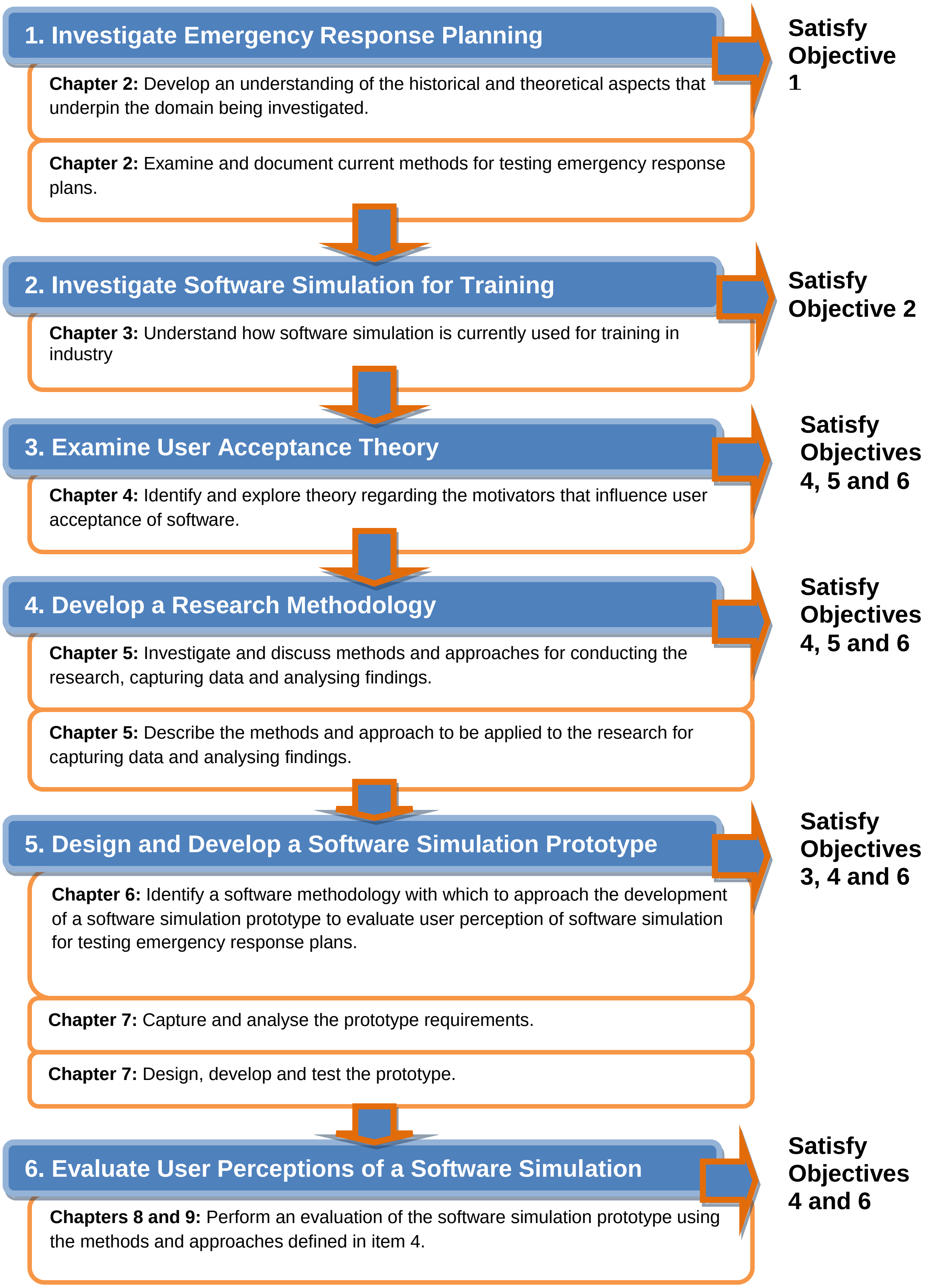


Figure 1Thesis Process Model

The research background and context are introduced in Chapter 1. The research aims and objectives and the knowledge the research serves to contribute are also described in the first chapter. Chapters 2, 3 and 4 provide the main literature review component of the thesis. Chapter 2 documents emergency planning legislation as applied to the UK gas industry. The aim of Chapter 2 is to provide an understanding of how legislation impacts on the UK gas industry’s responsibilities to develop and test emergency response plans. Chapter 2 also describes the methods currently used for testing emergency response plans.

The application of software simulation for training is examined in Chapter 3. A definition of the term software simulation and its meaning in the context of this research is provided. Software simulation applications employed to develop competency in response and applied skill in industry are described and the benefits they bring to their role documented. A framework for evaluating user acceptance is considered in Chapter 4. User acceptance frameworks are described and comparatively reviewed. The framework that underpins this research is presented.

The research methodology applied to the study is described in Chapter 5. A case study of the application of emergency response strategies by a UK gas network provider is introduced and described. The methods and procedures chosen to perform the case study are discussed. The use of a pilot study to test the virtual simulation prototype and the proposed research methods is considered.

The development of the software simulation prototype developed for evaluation is presented in Chapter 6. A description of the pilot study and the way in which it informed the development of both the prototype and the research methods is provided in Chapter 6. Chapter 7 describes the process of the evaluation of the virtual simulation prototype for conducting exercises to test emergency response planning strategies. The research sample are described and the methods used for the data capture process are documented. Chapter 8 comparatively evaluates the findings from both the tabletop role play and virtual simulation prototype case studies. The data analysis and key findings resulting from the comparative study are also presented in Chapter 8. Chapter 9 concludes the thesis, a summary of the key findings and recommendations for future work are considered along with a reflection of the research process.

The background to the research problem has been introduced in this chapter. The aims and objectives of the research to address the problem have been identified. The contribution to knowledge this study presents has been defined. The journey the thesis takes to achieve that contribution through the chapters therein has been presented. The following chapter looks at emergency response planning for large scale incidents and how it applies to the UK gas industry.

Chapter 2 Emergency Response Management and the UK Gas Industry

A background to emergency planning legislation as applied to the UK gas industry is presented in this chapter. Methods currently used for conducting emergency response planning strategies are examined and documented and the issues faced with current practice are highlighted. Further to this critical review of current practice, the chapter concludes with a premise that alternative approaches to emergency response planning strategies could offer potential enhancements to the testing of emergency response plans.

Failure in gas infrastructure can impact significantly upon individuals, communities and the environment (Mahgerefteh and Olufemi, 2006; Hazards Intelligence, 2005; Papadakis, 1998; Kulyapin et al., 1990). In the UK, emergency plans are drawn up in a considered attempt to mitigate the consequences of pipeline failure. Organisations that store and transport hazardous materials are legally required to prepare plans and regularly carry out simulation exercises to test them under the Control of Major Accident Hazards Regulations 1999 (COMAH).

Organisations that are bound to COMAH regulations are referred to within the regulations as COMAH operators and the locations the activities are conducted in, as COMAH sites (Great Britain. Health and Safety Executive, 1999). In some cases operators are required to have an on-site plan and an off-site plan. The plans detail the operator's policy for the prevention and mitigation of major incidents within their sites. Plans include such items as the location of facilities, contact details for agencies and people to be notified in the event of an incident

(Great Britain. Health and Safety Executive, 1999). The plan objectives as detailed in the COMAH regulations (Great Britain. Health and Safety Executive, 1999), schedule 5, Part 1, regulations 9(1) and 10(1) are to:

- contain and control incidents so as to minimise the effects;
- limit damage to persons, the environment and property;
- communicate necessary information to the public and responding agencies;
- provide for restoration and clean-up of the environment.

Details of the plans are to be shared with other agencies that are likely to respond in the event of a major incident. Agencies in this context may include organisations such as emergency responders who tend to be first at the scene like the Police and Fire and Rescue Service. The term agency also refers to organisations that have the knowledge and experience to make decisions about things affecting society on a larger scale, such as shutting off water mains, electricity or gas, or contributing to welfare and response and recovery.

UK gas infrastructure providers are bound by the COMAH and Pipeline Safety Regulations 1996 (PSR). Infrastructure providers are not responsible for the supply of gas, they are responsible for providing and maintaining the storage facilities and pipeline infrastructure used by the gas supply companies. There are five gas infrastructure providers in Great Britain: Scotland Gas Networks, Northern Gas Networks, National Grid, Southern Gas Networks and Wales and West Utilities. A case study of Northern Gas Networks (NGN) and their emergency response planning processes is conducted in this research.

2.1 A Historical Review of Emergency Response Planning Legislation in the UK

A major review of UK health and safety legislation occurred in the 1970's and 1980's in response to a number of major incidents (Table 1). A major incident is defined by the HSE as:

a significant event, which demands a response beyond the routine, resulting from uncontrolled developments in the course of the operation of any establishment or transient work activity."(Great Britain. Health and Safety Executive, 2010a)

The Advisory Committee on Major Hazards (ACMH) was created by the UK Health and Safety Commission (Great Britain. Health and Safety Executive, 2010) as a result of the Flixborough disaster. The Committee was formed to consider the potential problems of major hazards and make recommendations on the prevention and preparation for them. The Seveso Directive, published in 1982 in response to the Seveso disaster, set out to legislate health and safety implications of storing and transporting hazardous materials within Europe. The Seveso Directive was largely influenced by work carried out in the UK by the ACMH (Great Britain. Health and Safety Executive, 2010).

Further changes to health and safety legislation occurred in the 1980s in response to the Bhopal and Sandoz disasters. The Seveso Directive was amended twice in response to these incidents in 1987 and 1988, further amendments took place in 1992 when it was published as the Seveso II Directive and again in 2012 as the Seveso III Directive (European Commission, 2012). In the UK, the COMAH Regulations were also created in response to the Bhopal and Sandoz incidents

(Great Britain. Health and Safety Executive, 2010). These regulations enhanced the rigour of requirements placed on UK organisations in their approach to disaster response planning (Mannan et al., 2005).

Table 1 Legislation Changes in Response to Major Incidents

Year	Incident	Incident Details	Legislation Changes
1974	Flixborough	A leak from a cracked reactor at a chemical plant in Flixborough caused an explosion that killed 28 workers and injured a further 36.	Advisory Committee on Major Hazards created.
1976	Seveso	A rupture in a chemical reactor released a toxic cloud that spread ten square miles. The cloud contaminated land and vegetation, resulting in an estimated 2000 people being treated for dioxin poisoning.	Seveso Directive published.
1984	Bhopal	A chemical leak caused more than 2500 deaths.	Seveso II published and Control of Major Accident Hazards 1999 created.
1986	Sandoz Warehouse	Fire-fighting water contaminated with mercury and other chemicals polluted the Rhine, causing the death of half a million fish.	Seveso II published and Control of Major Accident Hazards 1999 created.

Emergency planning legislation has largely evolved in response to disasters. Rigorous procedures outlined in legislative regulations, undoubtedly contribute towards the safe keeping of individuals and the environment. Legislation, regulation and documentation alone do not prevent disaster, organisations must own and implement procedures required by regulations, when responding to a major incident and undertaking to mitigate potential consequences. Testing of emergency response plans is undertaken to better prepare organisations for major incident emergency response.

2.2 Emergency Response Planning Strategies

Emergency response strategies are required to be developed for high pressure gas pipelines. In the UK, such emergency response planning strategies are necessitated by legislation (Control of Major Accidents Hazard 1999). The strategies serve to mitigate the significant consequences of pipeline failure. The Advisory Committee on Major Hazards recommends that an emergency response planning strategy has three parts (Great Britain. Health and Safety Executive, 2010). These being:

1. Identification – COMAH operators should notify the relevant authority of sites that are required to comply with COMAH legislation.

2. Prevention and Control – Assessments of hazards, risks and consequences should be assessed and controls should be put in place to minimise their occurrence within the COMAH site.

3. Mitigation - Emergency response plans and procedures should be developed to reduce the effect of any incidents that may occur within a COMAH site.

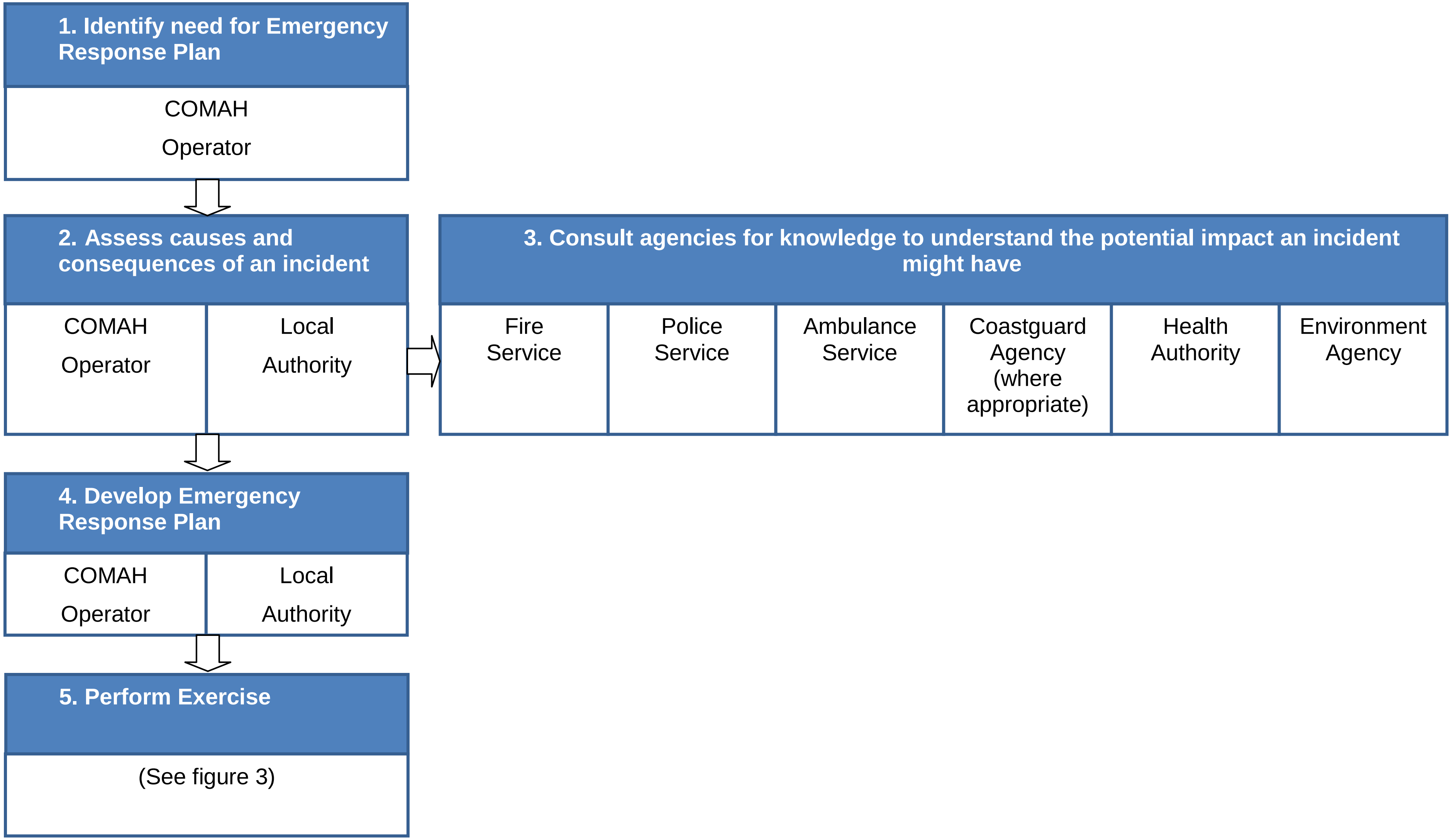
A requirement under COMAH legislation is the provision of an emergency plan for emergency preparedness. Emergency plans are required to be reviewed and tested every three years. COMAH legislation requires evidence to be submitted to the UK Health and Safety Executive (HSE) to demonstrate that the plans have been tested. Part 4, regulation 11(2) of the COMAH regulations state that the local authority is responsible for agreeing with the COMAH operator how the offsite plan is to be tested. Emergency response plans and the methods for communicating and testing plans are discussed in further detail.

2.2.1 Emergency Response Plans

Each COMAH site requires an emergency response plan to be developed; it is the responsibility of the COMAH operator to develop the plan in collaboration with the local authority (Great Britain. Health and Safety Executive, 1999). The plan describes the detail of the response required within each phase of a major incident. The first few hours after a major incident occurs is defined as the critical stage of an incident (Great Britain. Health and Safety Executive, 1999). Key decisions made within the critical stage of an incident have the potential to significantly impact on the outcome of an incident. A plan can be used to highlight the potential sequence of events that are likely to occur within an incident, thus assisting emergency responders in making key decisions towards minimising the consequences of an incident.

The first stage of the emergency response planning process involves not only assessing the likely causes of an incident but also the likely consequences (Great Britain. Health and Safety Executive, 1999). Once these details have been established then strategies can be put in place to minimise the effect of the consequences of an incident. Operators developing emergency plans for high pressure gas pipelines use in-house expert knowledge of potential issues relating to high pressure gas pipelines such as erosion and damage (Great Britain. Health and Safety Executive, 1999). The knowledge of relevant others such as the Fire Rescue Service, Police, Local Authority and any other organisations likely to be affected by an incident involving the COMAH site the plan relates to, are also drawn upon to understand the overall impact a potential incident may have (Great Britain. Health and Safety Executive, 1999). Figure 2 demonstrates the emergency response planning process and shows the organisations recommended by the HSE that should be consulted in that process (Great Britain. Health and Safety Executive, 1999).

Figure 2 Emergency Planning Process



A plan should include details of both normal and special control arrangements required to be performed in the event of an incident (Great Britain. Health and Safety Executive, 1999). Detail of people, resources and information required to perform the control arrangements are included within a plan (Great Britain. Health and Safety Executive, 1999). Activities such as who to call in the event of an incident and what actions should be carried out are all described within the plan. Emergency plans are working documents that are required to be kept up to date (Great Britain. Health and Safety Executive, 1999). An example of an emergency response plan is included within Appendix 3, such plans are confidential due to pipeline security sensitivity therefore any sensitive information has been removed from the sample plan.

Plans can be disseminated and tested using exercises, the Cabinet Office (Great Britain. Cabinet Office, 2010) provides guidelines for using exercises to test plans developed for major incidents. An exercise involves simulating a potential major incident to test emergency plans, procedures and develop staff competencies in performing their roles within an incident (Great Britain. Cabinet Office, 2010). The Cabinet Office (Great Britain. Cabinet Office, 2010) states the purpose of an exercise is to:

- validate plans;
- develop staff competencies and give them practice in carrying out their roles in the plans;
- test well-established procedures.

The information within a plan should be communicated to relevant organisations likely to respond to an incident involving the plan. COMAH legislation requires that plans are reviewed and tested with relevant organisations every three years and evidence that plans have been tested submitted to the UK HSE. The two main methods used for testing plans are tabletop and live role play (Great Britain. Cabinet Office, 2010). Methods for disseminating information within a plan and for testing plans are discussed further.

2.2.2 Disseminating Emergency Response Plans

Discussion exercises, steering and focus groups and emergency planning workshops are all approaches used to communicate plans to organisations (Great Britain. Home Office Publications, 1998; Great Britain. Health and Safety Executive, 1999). Discussion exercises are most suitable for disseminating information to groups of 8-12 people, generally from the same organisation (Wilson, 2000). One or more participants prepare material for the seminar and a group leader introduces the topic and leads the discussion, (Wilson, 2000). Discussion exercises tend to be low cost and are used to inform participants of developments in the emergency plan.

Steering and focus groups provide an opportunity to communicate information and ideas between representatives from different organisations (Great Britain. Home Office Publications, 1998; Great Britain. Health and Safety Executive, 1999). These groups are not only used to communicate the plan but they also give representatives from other organisations an opportunity to develop the plan further to accommodate the requirements of those organisations in the event of an incident.

Emergency planning workshops are designed to both communicate information within plans and to form relationships between representatives from relevant organisations. These workshops are also designed to form relationships between those representatives responsible for developing media links and public information help lines. Forming relationships through workshops, focus groups and steering groups prior to an incident has been shown to improve the facilitation of communication in live incidents (Great Britain. Home Office Publications, 1998; Great Britain. Health and Safety Executive, 1999).

Whilst each of these approaches provide an opportunity to discuss emergency planning content they lack provision for acting out and applying the plan to given scenarios. The Cabinet Office (2010) provides guidelines for using exercises to test plans developed for major incidents. An exercise involves simulating a potential major incident to: test emergency plans, test procedures and develop staff competencies in performing their roles within an incident (Cabinet Office, 2010). The Cabinet Office (2010) states the purpose of an exercise is to:

- validate plans;
- develop staff competencies and give them practice in carrying out their roles in the plans;
- test well-established procedures.

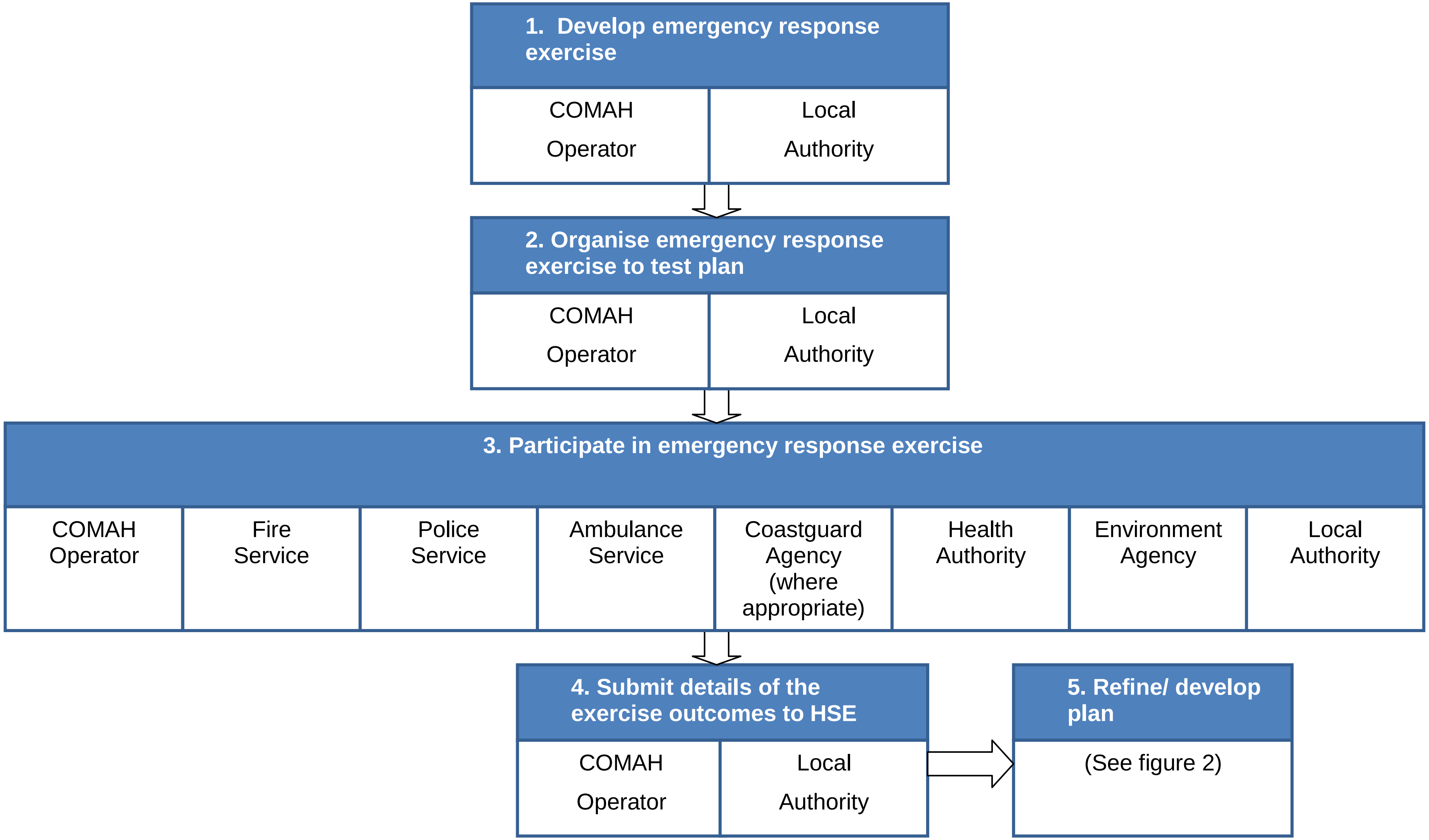
The Cabinet Office recommends using tabletop role play and live role play for exercises (Cabinet Office, 2010). Ideally representatives from all agencies that would normally respond to a live incident of the nature provided in the exercise would participate in the exercise. This is not always an option as agencies do not always have the physical or financial resources to make representatives available for participation (Cabinet Office, 2010; Hubbard et al., 2008; Crichton and Flin, 2001). The tabletop and live role play methods for testing plans are discussed further.

2.2.3 The Tabletop Role Play Approach to Testing Emergency Response Plans

The exercise involves a simulation of a potential scenario to test plans and procedures (Great Britain. Cabinet Office, 2010). Participants are grouped around tables with other participants that they would form task groups with during an real-world incident. Exercises are run either in a single room or in multiple rooms in the same building to test communication between partnering organisations (Great Britain. Cabinet Office, 2010). The exercises are designed to require a response from multiple agencies. Participants are expected to act out the scenario and role play the response their organisation would provide in the incident scenario, using the information supplied within the plan to support response decisions.

Tabletop role play exercises are developed in collaboration between the COMAH operator and the Local Authority (Great Britain. Cabinet Office, 2010). Upon completion of the exercise the COMAH operator and the Local Authority collaborate together to compile a report which details the outcome of the exercise and is submitted to the HSE. Figure 3 shows the process of the development of an emergency response exercise.

Figure 3 Emergency Response Planning Exercise Process



Tabletop exercises provide an opportunity to get members from partner organisations to interact together and understand the roles and responsibilities of each other's organisations, (Wilson, 2000). An exercise serves to test a plan, any amendments required to improve the plan are highlighted during an exercise and made after an exercise, hence there is no correct way to complete an exercise. Tabletop exercises require personnel from different organisations to attend at a single location, which makes them costly in terms of personnel resource exercises (McGrath et al., 2005; Campbell et al., 2008). None participation in this physical tabletop approach can cause a challenge to the viable testing of the plan.

2.2.4 Emergency Response Planning and Live Exercises

Live exercises range from small scale evacuation procedures through to a full blown simulation of an incident. They are particularly useful for testing "logistics, communications and physical abilities" (Great Britain. Cabinet Office, 2010). Live role play provides an opportunity for participants to test out the plan's procedures in a real setting. A live exercise can be costly, it involves organising a site, equipment, attendance from all likely responders such as front line, communication, emergency services, media, welfare and Local Authority personnel (Great Britain. Cabinet Office, 2010). Representatives from all agencies that would provide a response to real-world incident of the nature described within an exercise scenario are invited to participate in the live role play exercise. This is not always an option as agencies do not always have the physical or financial resources to make representatives available for participation (Great Britain. Cabinet Office, 2010; Hubbard et al., 2008; Crichton and Flin, 2001).

2.3 How Responders Learn to Prepare for an Incident

Exercises provide an opportunity to disseminate information about a plan and test the processes and procedures highlighted within a plan. Whilst some knowledge of incident response procedures can be gained from preparing and disseminating information in a plan, it does not necessarily prepare responders for dealing with incidents of failure (Binder, 2002; Quarentelli, 1988). Quarantelli (1988) suggests that in light of a live disaster situation, lines of communication are not necessarily clear. These lines of communication include those within and between responding organisations and between organisations and the public. Often when a disaster situation requires a response from multiple agencies, the chain of command can become unclear. Whilst an agency active in the response to the disaster has its own chain of command, there is the possibility that the chain of command between it and other agencies may break down. Quarentelli (1988, p.373) argues that "Exercise of authority difficulties stem from losses of higher echelon personnel because of over-work, conflict regarding authority over new disaster tasks, and clashes over organizational jurisdictional differences".

Tabletop and live role play methods provide an opportunity for agencies to meet face to face and thus form relationships before an incident has occurred. The development of relationships to encourage communication channels, may occur in these exercises, however not all personnel likely to respond to an incident may attend an exercise. Staffing commitments of agency representatives present limitations on their availability to attend exercises. Many responders rely on the knowledge passed down by their peers to respond to an incident, where they have not gained experience in participating an emergency response planning exercise. Staff change and information can get lost or misinterpreted over time, Perry and Lindell (2003, p.346) state that:

"Hazard vulnerability, organisational staffing and structure and emergency facilities and equipment have the potential for changing over time…as conditions change the written documentation must also change."

Responders lacking knowledge regarding plans and experience in applying them may result in a risk of the plans not being executed effectively. Oh et al. (2010) claim that emergency-related organisations, do not fully understand how to utilise the critical infrastructure, to reduce the impact of major incidents. The COMAH legislation only states that the emergency plans must be tested and reviewed by relevant agencies every three years. There is no requirement in the COMAH legislation that specifies all staff from each agency likely to respond to an incident, must attend a training exercise to test the plan. Perry and Lindell (2003) suggest that written plans should not be confused with emergency planning itself, rather a written plan is part of the planning process.

Planning for emergency preparedness is an evolutionary process, whilst some events can be predetermined and planned for, "new ways to deal with the unforeseen events evolve with the nature of the crisis" (Turoff, 2002, p.30). Emergency response exercises provide a method for both learning the plan and forming relationships with personnel from other organisations. The issues associated with current methods for testing plans are discussed further.

2.4 Current Problems with Testing Emergency Response Plans

Cost, complexities, availability and geographical dispersion of personnel are all cited as issues with tabletop and live role play simulation exercises (Campbell et al., 2008; McGrath et al., 2005). Tabletop and live role play events require organisation of a suitable location to conduct the exercise and on the personnel available to participate. Organising personnel from geographically dispersed organisations can be costly in terms of site use and personnel resources (Great Britain. Cabinet Office, 2010; Crichton and Flin, 2001). Most exercises are time consuming and can require “several months” of planning to coordinate availability of appropriate staff (Great Britain. Home Office Publication, 1998). Attendance of emergency response personnel with the appropriate specialist knowledge required to conduct exercises can be difficult to organise due to time and resource cost implications (Hubbard et al., 2008).

Tabletop role play lacks provision for visual and auditory cues that have been shown to enhance training in scenarios designed for combat and Police training (BinSubaih et al., 2005; Lampton et al., 1995; Miller and Thorpe, 1995). Software simulation offers an alternative approach to training environments that caters for audio and visual feedback, in addition to providing a means to deliver exercises simultaneously, across a wide geographical network. The use of software simulation for training in incidents of risk is examined in the next chapter.

Chapter 3 Software Simulation for Training

Software simulation offers great potential for the testing of emergency plans, it provides a controlled environment where decisions and responses can be audited and mistakes can be made without serious consequence (Smith and Carter, 2010; Tichon et al., 2003; Haller et al. 1999). Technology can allow exercises to be run simultaneously across multiple locations, providing opportunities for a wider range of participation (Churchill and Snowdon, 1998). Software simulation strategies can be used to enhance training or offer alternative opportunities to tabletop role playing methods (Jain and Mclean, 2006a; National Research Council, 2002).

Application of software simulation is exercised for activities and situations such as combat, flight training or emergency scenarios (Smith and Carter, 2010; Tichon et al., 2003; Haller et al. 1999; Miller et al., 1995). The adoption and application of software simulation for the development of response and applied skill, is well documented in industries such as aviation, military, medicine and the emergency services (Grant and Meadows, 2008; Macedonia, 2002; Crane et al., 2001; Huddlestone et al., 1999; Messina et al. 1997; Lampton et al., 1995).

The potential software simulation offers for training in emergency response strategies is examined. The term ‘software simulation’ is clarified and its application for training considered. Key issues regarding software simulated environments for training use and for testing emergency response planning strategies are identified and appraised within this chapter.

3.1. A Definition of Software Simulation

The terms virtual simulation and software simulation are used to refer to a broad range of environments. Hartman (1996) states the main feature of a simulation is that it allows a process to be imitated by another process and a simulation that is conducted using a computer is a computer simulation. The term computer is replaced by the term software in this thesis and used to mean a simulation that is conducted using software technology. The term virtual, when used in the context of a virtual simulation, brings new meaning to the word simulation as described here.

Stone (1992, p.85) describes four types of virtual systems that have evolved throughout the ages:

1. Printed texts (mid 1600s);
2. Electronic communication and entertainment media (1900s);
3. Information technology (1960s);
4. Virtual reality and cyberspace (from 1984 and beyond).

Stone describes how the first “virtual communities” were created through written texts, and attributes the creation of them to Robert Boyle who wrote a paper describing a scientific experiment in 1669 (Stone, 1992, p.85). Boyle used the paper to disseminate information about his experiment to people who had not witnessed the experiment, thus creating the first “textual virtual community” (Stone, 1992, p.85). The 1900s bore witness to the development of electronic communities through the invention of the telegraph, radio and television (Stone, 1992). Television and radio provided a one-way communication that could allow messages to be delivered to large audiences at the same time (Stone, 1992).

The 1960s witnessed the creation of information technology and in the mid 1970s virtual communities were based on online bulletin boards (Stone, 1992). Online bulletin boards allowed users to communicate with each other via textual messages that were displayed on the electronic bulletin board. During the 1980s a two-dimensional "cyberspace military simulation" known as SIMNET (SIMulator NETworking) was designed and developed by the Advanced Research Projects Agency (ARPA now known as DARPA) in collaboration with the US Army (Stone, 1992, p.89). SIMNET was a network of approximately 250 2D simulators that simulated a battle field simulation (Miller and Thorpe, 1995; Stone, 1992).

In the private sector virtual worlds were being developed that allowed users to create a virtual reality (VR), with virtual characters known as avatars that could interact with other users within the virtual space (Stone, 1992; Chip and Randall, 1991). The work carried out with SIMNET and in the private sector laid the foundations for further development in virtual technology such as fully immersive environments, using Cave Automatic Virtual Environment **(**CAVE) technologies and Head Mounted Displays (HMDs) (Ellis, 1994; Cruz-Neira et al., 1992; Stone, 1992).

This research sits within the third and fourth categories described by Stone: information technology, VR and cyberspace. It investigates how hardware and software infrastructures, can allow users to collaborate in an emergency response training task. Virtual environments (VEs) are environments that allow VR activities to take place. Ellis (1994, p.17) describes VEs as “interactive, virtual image displays enhanced by special processing and by non-visual display modalities such as auditory and haptic, to convince the users that they are immersed in a synthetic space”. Many formats for representing data or information are available within VEs, including 3D and 2D graphical representations, animation, text and audio (Churchill and Snowdon, 1998).

Riva (1999) describes VEs as both an interactive communication tool and an interactive communication interface. Riva (1999) states that when a single-user interacts with a VE, the VE is an interface to communicate information to the user. Furthermore, Riva (1999) suggests that the VE becomes a tool with which to communicate with other users when used in a multi-user environment. A distributed VE allows multiple users to interact with the same system whilst being geographically dispersed. A VE that supports collaborative activities between users that are geographically dispersed is known as a collaborative virtual environment (CVE) (Churchill and Snowdon, 1998).

The term software simulation as applied to this study refers to a broad range of VEs, combining both Stone (1992) and Riva’s (1999) definitions, it is both an interactive communication interface and an interactive communication tool, that takes place by way of computers. The simulation activities can range from conducting a conversation via a dedicated chat window, to interacting within a three dimensional space. This study examines a range of software simulations, to include fully immersive systems using HMDs, interactive desktop applications and distributed CVEs.

3.2. Software Simulation for Army Combat Training

One of the earliest investors in virtual software simulation techniques was the United States Army (Lampton et al., 1995; Miller and Thorpe, 1995; Stone, 1992). Experiments were carried out using three different types of virtual simulation techniques with army personnel:

1. physical mock-ups of combat vehicles with monitors showing a simulated view of the battlefield;
2. fully immersive environments using HMDs;
3. desktop software simulation environments.

Each of these environments are discussed in turn.

3.2.1. Physical Mock-Up Simulators

Physical mock-ups of tanks and helicopters were developed, each containing a monitor that represented the simulated view of the outside from the vehicle's window (Lampton et al., 1995; Miller and Thorpe, 1995). The physical layout of the mock-up represented that of real combat vehicles forcing participants to physically use the simulator in the same way they would a real vehicle. The experiments revealed that this method was suitable for training soldiers to use the vehicles in combat, but an alternative simulation would be required to support the training of soldiers who were on foot (Lampton et al., 1995).

3.2.2. Fully Immersive Environments

Fully immersive environments using HMDs were evaluated by the US Army to assess their suitability for training foot soldiers (Lampton et al., 1995). The HMDs provided the user with a three dimensional view of the combat simulation. The user was in control of navigating around the virtual simulation and interacting with objects presented within the field of vision. Individuals were able to use the VE to move, shoot and communicate with other soldiers. Whilst training in these areas was believed to be useful, the research found that the HMDs were costly and came with limitations on their performance (Azuma et al., 2001; Rolland and Fuchs, 2000; Lampton et al, 1995). Such limitations included:

- Low screen resolutions which were unsatisfactory for combat simulation;
- The equipment being too bulky to practically carry out physical tasks.
- Issues with neck strain caused by the HMD when used over long periods;
- Cost, miscalibration and screen lag.

3.2.3. Desktop Software Simulations

A third type of simulation involving a desktop VE was also investigated by the US Army (Lampton et al., 1995). The 3D virtual simulation was projected onto a screen and participants were given tasks or procedures to follow. The individuals carried out the tasks assigned to them, by navigating their way around the environment and interacting with virtual objects using input controls such as joysticks and keyboards. The same tasks completed with the HMDs were also carried out with the desktop approach. The study revealed that the practicalities associated with the use of a desktop approach improved performance (Lampton et al., 1995). The desktop display approach resolved issues associated with neck strain, portability and screen lag (Lampton et al., 1995).

VR simulation techniques revealed potential for training for conflict scenarios (Lampton et al., 1995). The experiments showed a variance in the performance of users, which revealed that users need to be provided with initial software and hardware training of VEs (Lampton et al., 1995). Findings revealed that due to the wide range of VE technologies available, research into the technological requirements of the training is just as important as initial equipment training. Physical simulation mock-ups are shown to enhance training of equipment and vehicles. HMDs provide a depth of view display that can enhance realism through visualisation. Both physical mock-ups and HMDs come at a high cost. HMDs present physical issues due to weight and portability. Desktop virtual displays provide a more convenient cost-effective solution to enhancing training scenarios through the use of audio and visual cues (Lampton et al., 1995).

3.3. Software Simulation in Healthcare Training

High fidelity patient simulators such as SimMan® and the Human Patient SimulatorTM are two simulators commonly used in nursing education (Leigh and Hurst, 2008). The simulators are full scale, interactive models of humans, that respond both verbally and physiologically to interactions (Leigh and Hurst, 2008). Individuals learn how to deal with patient scenarios by practicing clinical situations on the simulation models. These simulators are used to train students how to respond to situations they are likely to encounter in a clinical setting.

Marshall et al. (2001) argue that the use of simulators helps to improve the student's time-management skills, promotes leadership skills and helps to develop their critical thinking. Bremner et al. (2006) also found that students training with simulators feel more prepared and have increased confidence for entering live hospital experiences. Research by Henneman and Cunningham (2005) showed that students were able to learn by their mistakes, learn from their participation peers and identify gaps in their current knowledge.

3.4. Software Simulation in Training for Emergency Response

Software simulation is employed throughout the emergency services, from firefighting to emergency vehicle distribution (Jain and Mclean, 2003). Virtual environments have been found to be beneficial for preparing trainees with firefighting skills (Ausburn and Ausburn, 2004). Other uses include training fire and police services for search and rescue operations and for uncommon situations such as earthquakes or terrorist attacks (Campbell et al., 2008; Albores and Shaw, 2005; Sandia National Laboratories, 1999). The Hydra Immersive Simulation System is a simulated learning environment that enables real-time simulation of incidents (Alison and Crego, 2008). The system evolved from the Minerva system which was developed to support team-based decision making in public order incidents (Newland et al., 1997). Participants using the Hydra Immersive Simulation System are split into teams and allocated to a ‘pod’. A pod is essentially a room that contains the equipment to allow the participants to view a 3D animation of the incident in real-time. The pod includes CCTV and microphones which enable exercise facilitators to monitor the team’s actions and responses from a separate location. Telephones, fax machines, video footage and audio recordings are all equipment utilised within the Hydra pods.

The Hydra Immersive Simulation System offers a high fidelity approach to experimenting with visually realistic environments (Alison and Crego, 2008). DiFonzo et al. (1998) demonstrate that the level of realism provided in the Hydra simulation involves participants through active participation and presenting challenging tasks that mirror real-world tasks the users are familiar with. The simulations reproduce key features of real situations offering high-levels of realism (Alison and Crego, 2008; DiFonzo et al., 1998). DiFonzo et al. (1998) also argue that the Hydra Simulation provides a quick inexpensive approach to capturing high quality data from incident response exercises. Moving the equipment for the Hydra pods from one location to another is possible providing the location has the correct facilities to implement the equipment. Specialist transportation and knowledge are required to set up and install the equipment at a new location.

Simulated virtual environments can be produced less expensively than reproducing full scale models, making them a more cost effective, accessible training solution (Jain and Mclean, 2006a; Su and Shih, 2003; Gibson and Howard, 2000; Howard et al., 2000). The Department of Defense found that using software simulated exercises instead of live exercises could reduce training costs by 90% (Robinson, 2004). Campbell et al. (2008) argue that whilst paper-based workshops may be good for testing a plan, software simulations provide an opportunity to repeatedly test out scenarios with different strategies more easily. Testing a scenario with alternative strategies prepares emergency responders with a better understanding of what to expect at an incident (Jain and Mclean, 2003; Simpson, 2001). Software simulations also provide a platform to test different scenarios improving responder’s emergency preparedness (Jain and Mclean, 2005).

A study comparing tabletop role play and software simulated environments for training police in traffic response, revealed that the visual indicators provided in the virtual environment enhanced the training (BinSubaih et al., 2005). One participant claimed that he preferred the “computer experiment” because he felt he could “see things and live the incident more” (BinSubaih et al., 2005, p.6). The same participant also commented that he was able to concentrate more using the software simulation, because he was able to “walk around and examine details more closely” (BinSubaih et al., 2005, p.6). This claim was supported by other trainees, one of which remarked that the burden of imagination that was required in the tabletop environment, was removed through the use of graphics in the software simulation.

Realism of visual models plays an important part of training in VEs (Smith and Carter, 2010). Realism can be enhanced through use of historical data and existing reference models (Law and Kelton, 2000). Developing realistic, real-time models can incur high development costs and may also come with significant hardware and software costs (Smith and Carter, 2010). The balance of needs against available resources, can determine the type of VE that is developed (Smith and Carter, 2010; Smith and Duke, 2000). Many off the shelf solutions can be used to support the real-time elements of a simulation, but still require some element of technical expertise that many typical emergency response organisations do not have (Jain and Mclean, 2003). Conflicting requirements can lead to a trade-off in available features (Smith and Duke, 2000).

3.5. Distributed Learning Through Software Simulation Use

CVEs allow users to collaborate simultaneously across a distributed network from various geographical locations. Running exercises simultaneously across multiple locations, reduces time and cost implications and provides flexibility in resource scheduling (Jain and Mclean, 2005). Forester (1989) found that increased communication between emergency responders, increased trust and reduced confusion which improved the emergency planning process. Responders who have had a chance to train together in tabletop role play exercises, provide a more effective response than those who come together for the first time at an incident (Great Britain. Home Office Publications, 1998). A distributed simulation also allows simultaneous training of personnel at different levels of the incident management hierarchy (Jain and Mclean, 2003, 2006; Churchill and Snowdon, 1998). The integration of training at different levels is known to improve team cohesiveness and performance through the sharing of experience (Jain and Mclean, 2006).

Training for high risk, time-critical incidents that require a multi-agency response requires both knowledge of the activities to be performed and of how to perform them in collaboration with other organisations (Jenvald and Morin, 2004). The term situated learning describes learning as a process that occurs within a social context (Lave and Wenger, 1991). Studies carried out by Lave and Wenger (1991) revealed that novices learned from experts and that learning was a process of “participating in communities of practice” (Bird, 2001, p.95). A community of practice is described as a “group of practitioners who jointly hold a constructive view of the meaning of their subject knowledge” (Bird, 2001, p.95).

Social interaction is a critical component of situated learning, participants learn from the beliefs, behaviours and knowledge held within the community (Bird, 2001). In a study of a virtual learning environment, Bird (2001) found that virtual communities of practice can compete with physical communities of practice. Stone

(1992, p. 507) describes virtual communities as "…passage points for collections of common beliefs and practices that unite people who are physically separated".

Research into the effects of computer simulated activities showed that communication was improved through the ability of having access to relevant information on a larger scale(Simpson, 2001). King and Xia (1997) claim that face to face contact is the preferred method of communicating however, it is also argued that a positive change in attitude of using technology to communicate and learn, occurs through experience of technology (Stavrinoudis et al., 2005; King and Xia, 1997). Whilst it is not recommended that technology should replace face to face learning, rather, it can act as a tool which supports the learning process (Smith and Carter, 2010; Taber, 2007; Trelaven and Cecez-Kecmanovic, 2001).

Software simulation has been shown to enhance training in activities that may be too dangerous or costly to train in a live situation. The type of software simulation environment available to an organisation depends on the requirements of that organisation. Cost, performance and physical limitations all contribute to the suitability of the simulation of an activity. The use of visual indicators within software simulation enhances the learning experience. The literature shows that conducting training activities using software simulation can increase participant's confidence in dealing with live situations. Creating a simulation that is effective in training users requires an understanding of how users learn through software simulation.

Distributed learning poses different benefits and challenges to face to face learning, the literature relating to these differences have been investigated. The literature has shown that software simulation can enhance learning and that CVEs bring benefits to training distributed groups. The type of VE used is determined by a combination of users' needs and available resources. With users and technical needs met, the success of software simulation relies on the acceptance and use of users. The role user perception plays in that success is investigated further.

3.6. Perception and the Acceptance of Software Simulated Environments

It is often the case that many choices of software solutions are available for the same task. The success of the chosen solution not only depends on how able it is to perform the task, but also by how it is adopted by its users (Bowman et al., 2005; Olesen and Myers, 1999; Bowen, 1989; Davis, 1989; Young, 1984). Past experience and knowledge of technology, attributes to the attitudes and perceptions users have of technology (Stavrinoudis et al., 2005; Jee and Lee, 2002; McMillan, 2000a, 2000b; Wu, 1999; King and Xia, 1997). Reeves and Nass (1996) suggest that perceptions are more influential than reality, when it comes to users accepting new technologies for existing activities.

Individuals prefer to conduct tasks that they know will produce the desired results (Bandura ,1978). Individuals also choose software that they know is capable of conducting the task they wish to perform (Compeau and Higgins, 1995a, 1995b). Whilst a piece of software may be capable of producing the desired results, a user may not have experience at using that software, therefore not realising its capabilities. The more experience an individual has with software that produces the desired results, the more positive a reaction they will have towards it's appropriateness to complete a task (Stavrinoudis et al., 2005; King and Xia, 1997;

Compeau and Higgins, 1995a and 1995b; Carlson and Zmud, 1994; Davis and Bostrum, 1993; Nelson 1990).

If perception plays such a significant role in determining how individuals accept new technology, then understanding how to manage individual's expectations in order to create positive experiences is a key contributor in developing successful solutions (Stavrinoudis, 2005; Morrison, 1998; King and Xia, 1997). Lee (2000) suggests that when developing new technology, the provision of features is not as important as understanding how the users perceive and experience those features.

Perceived usefulness and perceived ease of use directly impact an individual's acceptance and use of software (King and Xia, 1997; Igbaria et al. 1995; Howard and Mendelow, 1991; Davis, 1989). Prior computer experience, representing individual use, skills and comfort with the technologies, contribute towards influencing user beliefs with respect to computer technologies (Davis and Bostrum, 1993). Increased experience is likely to enhance user confidence in their ability to use computers for performing tasks (Kraemer, et al., 1993; DeLone, 1988). Opportunities to gain experience using computers are found to influence users' beliefs about technologies (Rivard & Huff, 1988).

The study of how user experience affects an individual's perception, of the appropriateness of a technology to perform a task, is "underemphasized" (King and Xia ,1997, p.877). Perceived usefulness is defined by Davis (1989, p.320) as "the degree to which a person believes that using a particular system would enhance his or her job performance". Even if an individual believes that technology will allow them to perform a task better, if they perceive it to be difficult to use they may also reject it (Davis, 1989). Therefore, ease of use is described as “the degree to which a person believes that using a particular system would be free of effort” (Davis, 1989, p.320). Early studies conducted by Davis found that perceived ease of use and perceived usefulness significantly correlated with system use.

Davis (1980) developed the theory of perceived usefulness and perceived ease of use further to create the Technology Acceptance Model (TAM). The TAM models how the acceptance and use of technology by individuals is both influenced by a user’s perceived usefulness and their perceived ease of use of the technology. The TAM is an extension of Ajzen and Fishbein's (1980) theory of reasoned action. Venkatesh and Davis (2000, p.186) demonstrated how "social influence and cognitive instrumental processes" played a role in determining the perceived usefulness of an application. The TAM was further extended to include elements of social influence and cognitive instrumental processes and became known as TAM2 (Venkatesh and Davis, 2000). A detailed discussion of the TAM is provided in the next chapter.

3.7. A Summary of the Potential of Software Simulation for Training.

The term software simulation in the context of this research has been clarified and the use of virtual software simulation for training has been outlined. The literature shows that software simulation provides a controlled and cost effective method for conducting training activities where live training would be dangerous or costly. Improved competence, increased cohesiveness and effective team incident management are all attributed to using software simulation for learning. Software simulation provides the ability to test a wide range of repeatable scenarios.

Distributed CVEs provide greater flexibility through providing access to participants that are geographically dispersed. The perception individuals have about technology can influence whether or not the technology is accepted. The theoretical framework provided in the TAM underpins the methodological approach taken in this study. A detailed investigation into the TAM model and how it will be applied as a framework to conduct this study is provided in the following chapter.

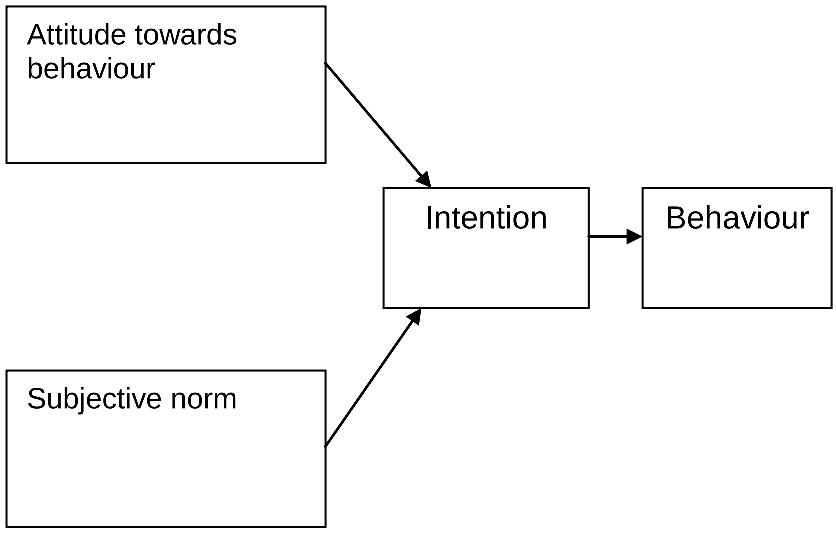
Chapter 4 User Acceptance Theory and Evaluation Frameworks

Several models have been developed to investigate user acceptance such as: Theory of Reasoned Action (TRA) (Fishbein and Ajzen, 1975); Theory of Planned Behaviour (TPB) (Ajzen, 1985); Technology Acceptance Model (TAM) (Davis et al., 1989), TAM2 (Venkatesh and Davis, 2000) and the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh, 2003). Despite all of these other models, this study focuses on the TAM, as it provides the most relevant constructs for an evaluation of a preliminary prototype that is not implemented and in use within an organisation. The models are described and their limitations considered.

4.1. The Theory of Reasoned Action

The TRA was developed to understand and predict user's behavior towards technology (Ajzen and Fishbein, 1980; Fishbein and Ajzen, 1975). This is achieved through identifying and measuring the behaviour in question. The TRA claims individuals consider their actions and the resulting consequences before committing to a given behaviour (Ajzen and Fishbein, 1975, 1980). The model presented in the TRA (figure 4) tries to identify the determinants of the behavioural intentions an individual acts upon (Ajzen and Fishbein, 1980).

Figure 4 Theory of Reasoned Action (adapted from Ajzen and Fishbein, 1989)



An individual's intention to perform a given behaviour is a central factor to the TRA (Ajzen, 1991). Attitude toward behaviour and subjective norm are identified as being the two determinants that influence an individual’s behaviour. Attitude refers to an individual’s positive or negative evaluative affect about performing a specific behaviour (Ajzen, 1991; Ajzen and Fishbein, 1980). Subjective norm highlights an emphasis of the individuals perception of social pressure through peer reaction on whether they perform or not in a given situation (Ajzen and Fishbein, 1980). Thus TRA attempts to explain why people hold certain attitudes and subjective norms.

4.1.1. Recommendations and Limitations of Using the Theory of Reasoned Action

The TRA received empirical support from early studies (Fishbein and Ajzen, 1975; Ryan and Bonfield, 1975; Ajzen and Fishbein, 1980) but later studies focused on understanding the limitations of the theory (Legris et al. 2003; Bagozzi, 1984; 1982; 1981; Saltzer, 1981). Despite the TRA capturing the internal variables that impact on behaviour it was criticized for failing to measure the external variables or motivational factors that determine behaviour (Davis et al., 1989; Davis, 1980). For instance, motivational factors, such as the motive to succeed, incorporate all the influences of the environment surrounding the individual which may influence an individual's behaviour (Ajzen, 1991).

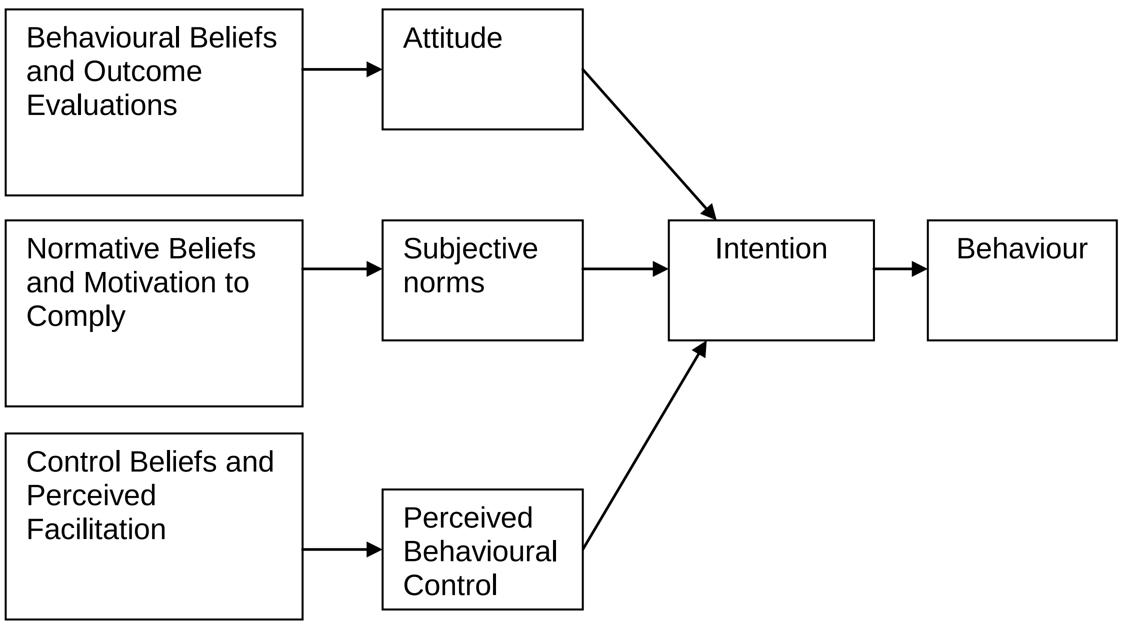
Another concern is that before the TRA can be applied, the external variables that influence beliefs on a behavior need to be identified with an additional preliminary study, which makes the model a costly method (Davis et al., 1989; Ajzen and Fishbein, 1980; Fishbein and Ajzen, 1975). The TRA failed to identify motivational processes that impact on user acceptance of software (Davis, 1980). Therefore the model is considered inadequate because it doesn't capture fully the user's motivation for acceptance and use of software.

4.2. The Theory of Planned Behaviour

The TPB (figure 5) was developed as an extension to the TRA and posits that an individual's behaviour is explained by their behavioural intention which is jointly influenced by attitude, subjective norms and perceived behavioural control (Chau, 2001, p.701; Ajzen, 1991). Perceived behavioural control refers to the control an individual perceives they have over the performance of behaviour (Mathieson 1991; Ajzen and Madden, 1986). Behavioural beliefs refer to the perception that a certain behaviour will lead to a likely outcome (Mathieson, 1991; Ajzen and Madden, 1986). An outcome evaluation is a rating of an individual's desire of the outcome, such as "using the system will save time compared to current methods" (Mathieson, 1991, p.176) and involves a variety of processes:-

- A normative belief is the belief and individual holds about referent other's opinions with regards to their own behaviour (Mathieson, 1991; Ajzen and Madden, 1986).
- Motivation to comply is the extent the individual wants to comply in order to perform the behaviour they believe their referent other wants to see (Mathieson, 1991).
- A control belief is the perception an individual has that the skills, resources and opportunities are available to perform the required behaviour (Chau, 2001; Mathieson, 1991).
- Percieved facilitation is an individual's perception of how important it is to have those resources in order to achieve a goal (Mathieson, 1991).

Figure 5 Theory of Planned Behaviour (adapted from Mathieson, 1991)



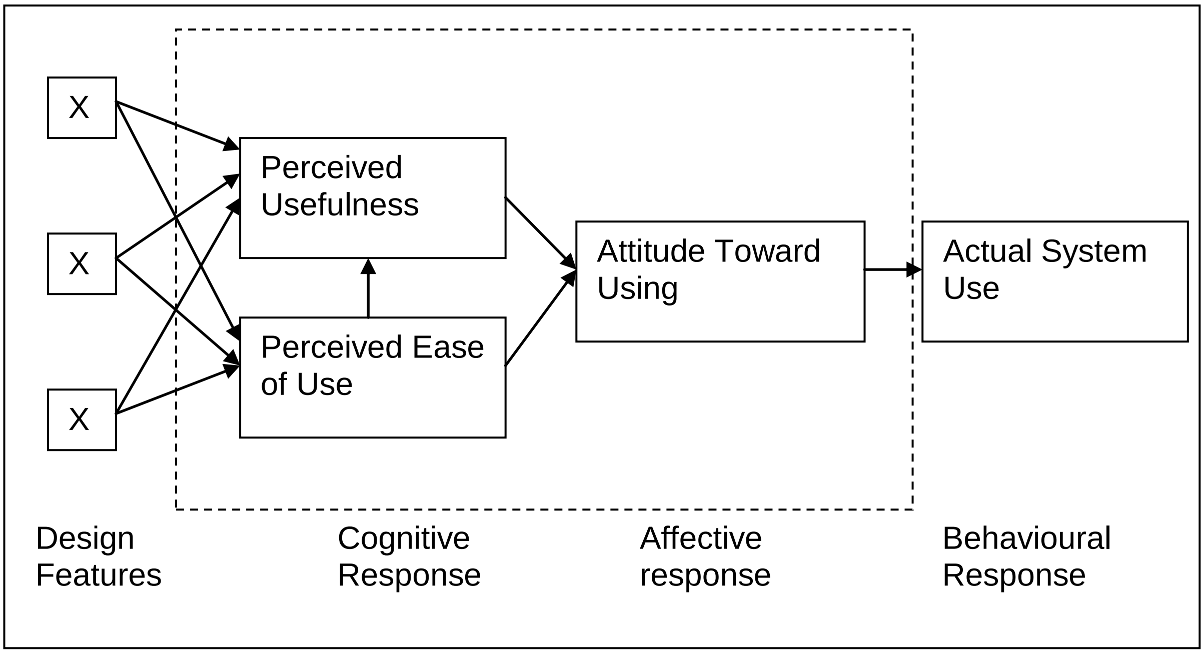
4.2.1. Recommendations and Limitations of Using the Theory of Planned Behaviour

Despite the apparent flexibility of the TPB it is considered a costly solution as the constructs are not measured the same way for every situation (Mathieson, 1991). For instance, each study that uses the TPB requires a pilot study to identify referent groups, relevant outcomes and consistent variables across each context of use (Mathieson, 1991). Different user groups may focus on different outcomes they desire from the system, requiring different instruments to be developed and tailored for each group (Mathieson, 1991). Exercises designed to evaluate emergency response planning strategies involve participants from many user groups. To apply the TPB to evaluating the prototype system for evaluating emergency response planning strategies would require TPB instruments to be developed for each group.

4.3. The Technology Acceptance Model

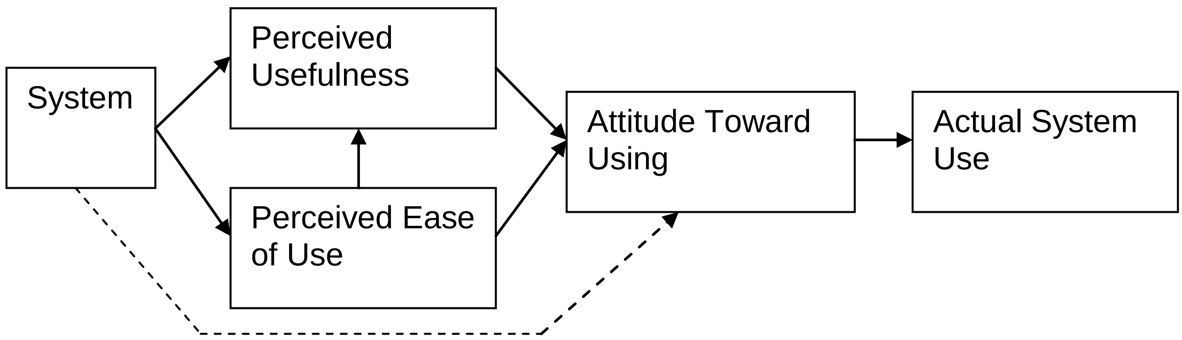
The TAM is the most widely used model to evaluate technology acceptance and use (Holden and Roy, 2011; Chuttur, 2009; Park, 2009). The model was developed by Davis (1980) who proposed that software use is determined by user motivation which is predominantly established by the actual behavioural outcome, that is, whether they use it. Davis developed the TAM in response to the lack of availability of motivational constructs in the TRA. The proposed TAM model (figure 6, taken from Davis, 1980:24) included a set of questions designed to capture and measure motivational variables that influence the acceptance and use of software features (Davis et al., 1989). The model was developed to evaluate the user acceptance of software prototypes. The results were intended to highlight the variables that affected user acceptance to inform designers and developers of any changes required to the software (Davis et al., 1989; Davis, 1980).

Figure 6 Technology Acceptance Model.



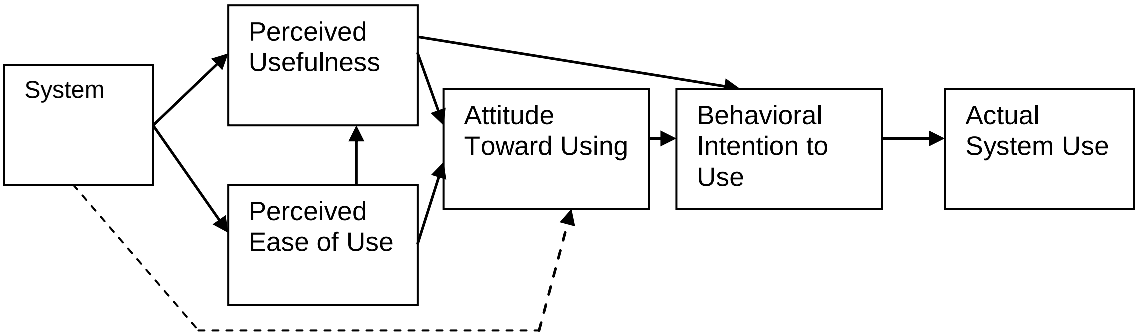
The TAM describes how 'attitude towards using' software is the outcome of a set of processes which cover; how useful the user perceives the software to be and how easy they perceive it will be to use (Davis, 1980). Perceived usefulness is subjective and determined by how the individual believes the software to enhance their own job performance. Davis (1980) states ease of use is directly and positively correlated to an improvement in performance. With perceived ease of use being determined by the reduction of physical and mental effort. Therefore, Davis (1989) developed a set of questions for measuring perceived usefulness and perceived ease of use, the TAM was modified to include these instruments (figure 7).

Figure 7 Technology Acceptance Model.



The TAM was developed further (figure 8) and extended to include behavioural intention to use (Davis et al., 1989). As with TRA's behavioural intention measurement, TAM behavioural intention to use determines computer usage, but it differs from the TRA's definition in that perceived usefulness and perceived ease of use is a parallel process (Davis et al., 1989). The TAM now described usage behaviour as a function of behavioural intention which is a function of attitude towards using, which demonstrates favourable or unfavourable feelings towards using the system (Taylor and Todd, 1995). Furthermore attitude is also determined by perceived usefulness and perceived ease of use. Perceived usefulness is considered to reflect an individual's belief that using the technology will improve job performance which also determines attitudes towards ease of use (Taylor and Todd, 1995).

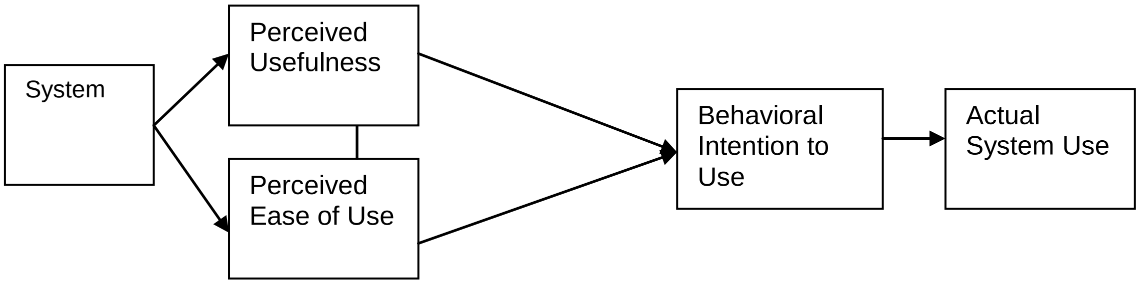
Figure 8 Technology Acceptance Model.



The final model (figure 9) was used in a longitudinal study on user's intention to use word processing software (Davis et al., 1989) and involved gathering data from 107 MBA students over four semesters of their program. It utilised a questionnaire containing measures from both the TRA and the TAM that were administered after a one hour introduction to the software. A second questionnaire was administered 14 weeks later which also contained measures from both the TRA and the TAM. The study revealed that perceived usefulness and perceived ease of use, both had a direct influence on behavioural intention, removing the need for having the attitude toward using element.

Finally, both Davis (1980) and Davis, et al. (1989) found that attitudes "do not fully mediate the effect of perceived usefulness and perceived ease of use on behavior" (Davis, 1989, p.335), therefore the attitude towards construct was removed from the TAM model (figure 8). However, the success of this final adjustment is inconclusive as subsequent studies (Schepers and Wetzels, 2007; Sun and Zhang, 2006; Venkatesh and Morris, 2000; Venkatesh, 2000; Venkatesh and Davis, 2000; Davis, 1993) have varying results, which appear to support the need for attitude.

Figure 9 Technology Acceptance Model.



4.3.1. Perceived Ease of Use and Perceived Usefulness

It is concluded that the two main constructs of the TAM are to be perceived ease of use and perceived usefulness. If an individual perceives a system to be easy to use but don't perceive it to be useful they won't use it. Self-efficacy has been identified as a determinant of perceived ease of use (Venkatesh and Davis, 1996). However, self-efficacy can be improved with training, thus increasing the user's perception of perceived ease of use and in turn the acceptance and use of the system (Venkatesh and Davis, 1996).

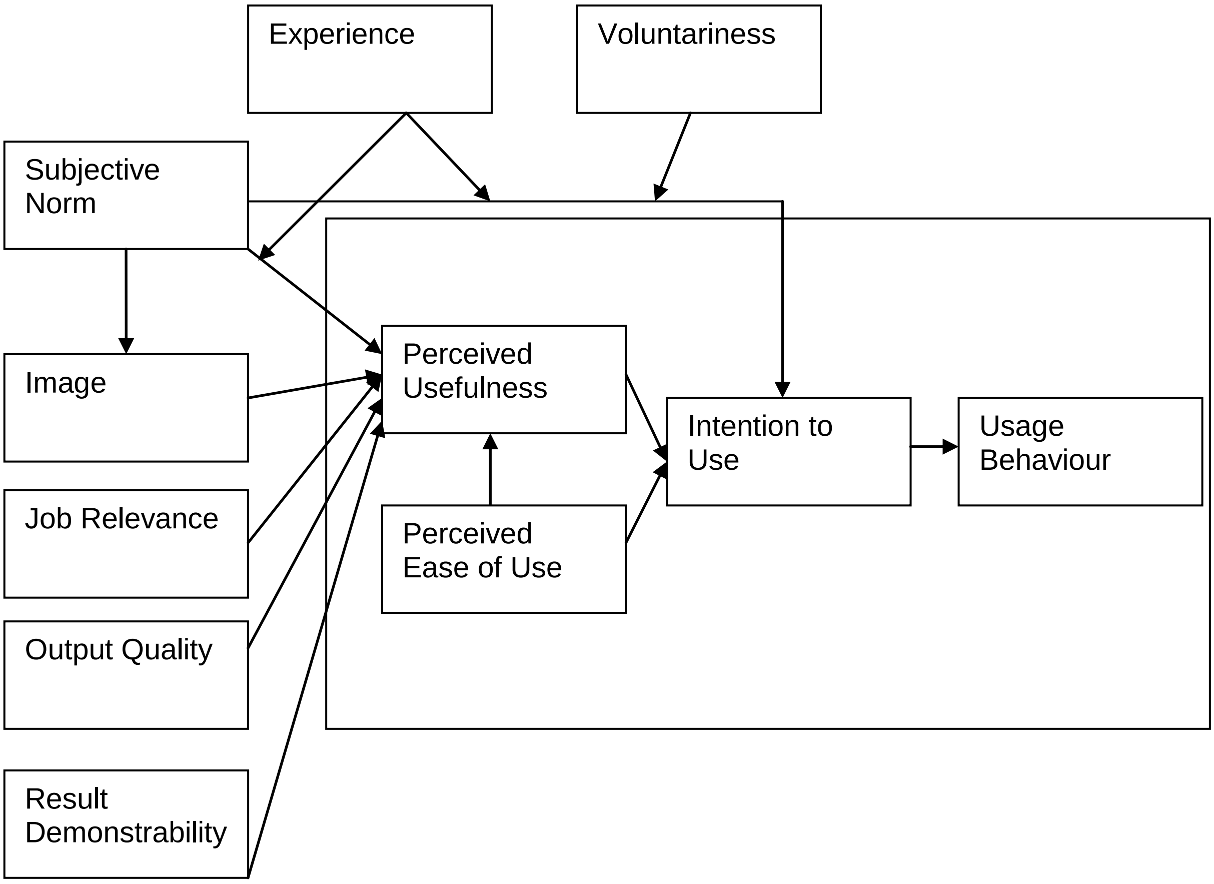
4.4. Perceived Usefulness and the TAM2

A criticism of TAM was that it did not include factors such as social influence and cognitive processes (Mathieson, 1991; Venkatesh and Davis, 1996; Venkatesh and Davis, 2000), whilst social influence and cognitive processes have been identified as having a substantial role on perceived usefulness in longitudinal studies (Venkatesh and Davis, 2000). These studies highlight the role of social influence and cognitive processes on usage intentions which lead to a further development of the TAM which was extended to include these instruments (figure 10).

The first study investigated 48 floor supervisors of a manufacturing firm who were being shown a system for their day to day studies. Use of the new system was voluntary and the participants received two days training of the new system. The second study involved 50 members of a financial services department. The system project involved moving the existing system onto a Microsoft Windows Operating system. Participants were given the option to continue using the existing system whilst the new system was introduced. A one and a half day training program was provided. The third study researched 51 employees of a small accounting firm and the introduction of a new Microsoft Windows-based customer account system. The use of the new system was mandatory and participants were given a one day training program. The final study investigates 51 employees of a small international investment banking firm. The system introduced was designed to assist the analysis of creating financial stock portfolios. The new system was developed from a different vendor and had a different look and feel, a four hour training program was provided.

The studies described (Venkatesh and Davis, 2000) illustrated the importance of the role of social influences on usage intentions has been illustrated, in addition to the influence of cognitive processes on affected judgments about a system's usefulness (Venkatesh, 2000). This lead to the further adaptation of the TAM to include elements of social influence and cognitive instrumental processes and became known as TAM2 (figure 10), (Venkatesh and Davis, 2000).

Figure 10 TAM2 model (Venkatesh et al., 2000)



Social influence processes were identified as consisting of three contributing factors: subjective norm, voluntariness and image. Influenced by the TRA, subjective norm is a construct that implies that a person's perception of something is based on what their peers think that perception should be (Venkatesh and Davis, 2000; Fishbein and Ajzen, 1975). Voluntariness refers to whether or not the software is being used under mandatory or voluntary circumstances (Venkatesh and Davis, 2000; Hartwick and Barki, 1994). Subjective norm was identified as having the greatest impact on determining usage intentions for mandatory but not for voluntary systems (Venkatesh and Davis, 2000).

The image factor refers to one's self image which is defined as the impact of use and innovation on an individual's status within that working environment (Moore and Benbasat's, 1991). Image seems to be positively influenced by subjective norm positively which has a direct impact on perceived usefulness (Venkatesh and Davis, 2000). However the review of subjective norm as a determinant of behaviour is mixed and therefore was excluded from the TAM (Venkatesh and Morris, 2000). As users gain experience with software over time, they rely less on social influence to inform their perception or opinions of software (Venkatesh and Davis, 2000).

From the cognitive perspective, four factors have been identified as determining perceived usefulness: job relevance, output quality, result demonstrability and perceived ease of use. The degree to which a user believes a system is relevant to their job, contributes to the acceptance of new processes or systems (Venkatesh and Davis, 2000; Goodhue, 1995; Leonard-Barton and Deschamps, 1988; Vessey 1991). The TAM2 proposed that individuals consider how well a system performs a task, over and above what the system is capable of, meaning that perceived output quality determines perceived usefulness (Venkatesh and Davis, 2000; Davis et al., 1992). Result demonstrability implies that users are more likely to form positive perceptions of the usefulness of a system, if usage demonstrates positive results (Venkatesh and Davis, 2000; Agarwal and Prasad, 1997).

Studies conducted by Venkatesh and Davis (2000) demonstrated that the relevance a user associates with a system to perform a task positively contributes towards user acceptance. However, the output quality of a task was found to be more relevant to users than job relevance (Venkatesh and Davis, 2000). Perception of results demonstrability was also found to determine perceptions of ease of use, resulting in a positive attitude towards the perceived usefulness of an application (Venkatesh and Davis, 2000). As with the TAM, the TAM2 retains that perceived ease of use is a direct determinant of perceived usefulness (Venkatesh and Davis, 2000).

4.5. Recommendations and Limitations for Using the Technology Acceptance Model

The TAM is a useful model for capturing external variables on “internal beliefs, attitudes and intentions” (Davis 1989, p.985). Lederer et al. (2000) recorded more than 15 studies published over a period of 10 years ranging from 1989-1999, which examined various relationships between the constructs identified within the TAM. King and He (2006) identified 88 studies published using the TAM. The studies were testing technologies such as word processing, telemedicine software, electronic mail, the internet, personal computers and virtual reality (Bertrand and Bouchard, 2008; King and He, 2006; Lederer et al., 2000). The published studies demonstrate that TAM is a valid and robust model to use in the understanding of technology acceptance. A list of relevant studies conducted using the TAM or variations of the model are given in table 2. The studies provided in table 2 demonstrate empirical support for the use of the TAM to evaluate user perception and acceptance of software prototypes.

Table 2 Related Studies (adapted from Fetscherin and Lattemann, 2008)

Author(s)	Model	Software Studied	Participants
Davis (1989)	TAM	Email, XEDIT	264 MBA Students
Straub et al. (1995)	TAM	V-Mail	458 Employees
Chau (1996)	Modified TAM	MS Word, MS Excel	285 Users
Szajina (1996)	TAM	Email	61 MBA Students
Gefen and Straub (1997)	Extended TAM	Email	392 Workers
Arbaugh (2000)	Extended TAM	Learning Space	97 MBA Students
Lederer et al. (2000)	TAM	WWW	163 Users
Brown (2002)	TAM	WebCT	78 Students
Chen et al. (2002)	TAM	Virtual Stores	228 Students
Hubona and Burton-Jones (2003)	TAM	Email	96 Corporate Staff, 122 Governmental Staff
Lee et al. (2003)	Extended TAM	AIDE (Web based collaboration, distance learning technology)	31 Students
Venkatesh et al. (2003)	UTAUT	Online Meeting Manager	54 Employees
Hsu and Lu (2004)	TAM	Online Games	233 Users
Ong et al. (2004)	TAM	E-Learning	140 Engineers
Shih (2004)	TAM	Internet	203 Workers
Van Der Heijden (2004)	TAM	Websites	828 Website Subscribers
Wang et al. (2004)	TAM	Instant messaging Service	437 Students
Ngai et al. (2005)	TAM	Web Course Tools	836 Students

4.5.1. Recommendations and Limitations of the Technology Acceptance Model

Although the TAM is an established model used to determine the likelihood of acceptance and use of software technologies it is not without limitations. Many studies exist applying the TAM support the claim that perceived ease of use is an antecedent of perceived usefulness and perceived usefulness directly influences whether or not a user accepts a system and uses it, (Venkatesh et al., 2003; Teo et al., 1999; Gefen and Straub, 1997; Igbaria et al., 1997; Szajona, 1996; Taylor and Todd, 1995; Adams et al., 1992; Davis et al., 1989). The TAM lacks methods for explaining the antecedents to perceived usefulness and perceived ease of use (Benbasat and Barki, 2007).

Items such as system design and evaluation may have a direct impact on perceived ease of use and perceived usefulness. Many iterations of the TAM exist in an attempt to provide a range of explanations for the belief perceptions of perceived usefulness and perceived ease of use (Benbasat and Barki, 2007). Modified versions of the TAM have included many different belief constructs, however they have only served to identify one set of belief perceptions, either perceived usefulness or perceived ease of use (Benbasat and Barki, 2007).

4.6. The Unified Theory of Acceptance and Use of Technology

The Unified Theory of Acceptance and Use of Technology (UTAUT) was developed by Venkatesh et al. (2003) and extends the original TAM model to include: performance expectancy, effort expectancy, social influences and facilitating conditions as the antecedents to perceived usefulness and perceived ease of use.

4.6.1. Effort Expectancy and Social Influence

Effort expectancy is defined as the amount of effort that a user perceives they will need to put into learning how to use a system (Venkatesh et al., 2003). In studies applying the UTAUT, effort expectancy and social influences were found to be most significant particularly in female older workers (Venkatesh et al., 2003). Social influence is defined as how much an individual perceives that others believe he or she should use a system (Venkatesh et al., 2003). It has been demonstrated that social influences are not significant if you don't include moderators such as experience and voluntariness (Venkatesh et al., 2003). Radzuwelt et al. (2013) argue that social influence should be excluded within the studies of prototypes as the systems are not introduced into working practice at the time of evaluation.

4.6.2. Facilitating Conditions

Facilitating conditions are defined as the degree to which an individual believes an organisation and technical infrastructure support the use of a system (Venkatesh et al., 2003). Facilitating conditions have only been shown to be significant for older workers in the later stage of experience of the software (Venkatesh et al., 2003).

This PhD study is of a prototype evaluation; as such the TAM extensions provided in the UTAUT relating to facilitating conditions are not relevant to this study. However, the age range of participants within this research range from 23-53, age may show significance within the attitudes of users towards the software simulation prototype for emergency response planning and therefore age will be considered within the PhD study.

4.6.3. The Research Evaluation Framework

The focus of the software prototype in this PhD study is on facilitating the testing of the plan virtually. It is not focused on enhancing aspects relating to user performance, effort or social dynamic. The perceived need for analysis to include extended aspects of the UTAUT is not evident. The software prototype is not testing comparisons with an existing virtual desktop approach. As such the extended focus of the UTAUT is not considered relevant to the core objectives of this research study.

4.7. The Research Evaluation Framework

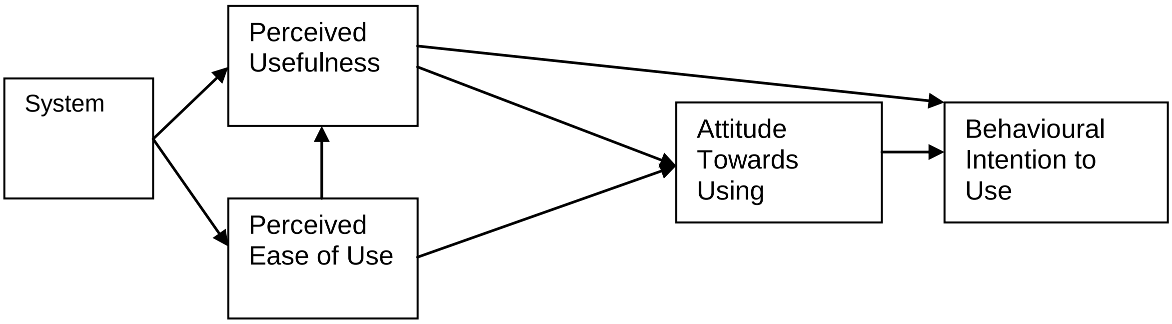
The evidence used within this review identifies that all of the models are adequate but insufficient and that their adoption is purely context dependent. A prototype is to be evaluated in this PhD study, the information on perceptions, beliefs and attitude captured during the evaluation are based on the user's understanding of the prototype and not on their experience of using a fully implemented software system. This research serves to measure the perception and intention to use the prototype, therefore acceptance and actual use are outside the scope of this study.

The use of modified and extended or varied models of the TAM have demonstrated that reliable results can be achieved without capturing and evaluating all constructs defined within the model (Radzuwelt et al., 2013; Fetscherin and Lattemann, 2008; Legris et al., 2002). If the system being evaluated is still in development, constructs designed to capture and evaluate actual technology use are not relevant (Chau and Hu, 2001). Social influence should be excluded within the studies of systems that are not introduced into working practice at the time of evaluation (Radzuwelt et al., 2013).

The research sample used within this PhD research are representative of participants involved in emergency response planning strategies within the UK gas industry. Only one female is present within the study, therefore gender is not considered for investigation within this research. Effort expectancy is most significant in older female users (Venkatesh et al., 2003), therefore effort expectancy is not seen as a significant factor that will influence the acceptance and use of the prototype.

The following elements are retained from the TAM and applied to this study: the concept of perceived ease of use and perceived usefulness, intention to use and attitude towards using. The decision to retain attitude towards using as a determinant of intention to use is based on the varying recommendations on including it (Shepers and Wetzels, 2007; Sun and Zhang, 2006; Venkatesh and Morris, 2000; Venkatesh, 2000; Venkatesh and Davis, 2000; Davis, 1993; Davis et al., 1989). This PhD research is designed to capture beliefs relating to Perceived Ease of Use (PEU), Perceived Usefulness (PU), Behavioural Intention to use (BI) and Attitude Towards using (AT). A deconstructed model of the TAM demonstrating the constructs applied to this study is shown (figure 11).

Figure 11 Research Model



Technology acceptance theory has been discussed in this chapter. The TRA, TPM, TAM and the UTAUT have been described and their limitations considered. A model to inform the research design which evaluates user perception of a software simulation prototype for testing emergency response planning strategies is proposed. The methods used to apply the research approach based on this model are discussed in the next chapter.

Chapter 5 Research Methodology

This chapter presents a methodology for researching user acceptance of software simulation for emergency response planning within the context of UK gas infrastructure. A case study approach for gathering information to support the design and development of a software prototype is considered. The organisation that provides the case study for this research is introduced in this chapter. The application of the research model that underpins the study is discussed. Methods for observing and capturing information relating to participant attitudes on current practice and a proposed alternative software approach are described. The use of a pilot study to test the data capture process is considered.

5.1. A Case Study Approach

Case studies enable researchers to study the subject in its natural setting (Benbasat et al., 1987). Questions can be asked about the 'how' and the 'why' things are the way they are, to gain insight into the "nature and complexity of the processes taking place", (Benbasat et al., 1987, p.370). A case study is most suited to multiple data collection methods (Maxwell, 1996; Kaplan and Duchon, 1988; Kaplan, 1985; Denzin, 1970). Multiple methods can be used to gather information about people, groups or organisations (Kaplan, 1985). Triangulation is the theory which describes an approach that uses combined methods. Ammenwerth et al. (2003) note that triangulation supports the reliability and validity of evaluation studies.

A case study is effective when the boundaries of the research are not clear at the onset. Case studies allow the study of the processes and people in their natural environment, rather than a controlled experiment (Benbasat et al. 1987). Supported throughout research applying the TAM, case studies have been used to capture the attitudes of users towards perceived usefulness and perceived ease of use of software (Hubona and Burton-Jones, 2003; Venkatesh et al. 2003; Lederer et al., 2000; Chau, 1996).

A case study of NGN provides the context of this study. Existing methods employed by NGN for conducting exercises to test emergency response plans to satisfy COMAH and PSR legislation are examined. The case study serves to understand the existing tabletop role playing method and the outcomes it intends to achieve. A secondary role of the case study serves to capture data about an exercise to inform the requirements specification of the software simulated alternative approach.

The findings from the preliminary case study serve to address objectives 1, 2 and 3 of the research which are:

1. To examine and document current practice for emergency response planning exercises, for high pressure gas pipelines;

2. To investigate and review the application of software simulation as a tool for facilitating the testing and training of emergency response planning strategies;

3. Identify and review frameworks and qualitative methods in order to enable the development of a methodology for capturing, measuring and evaluating user acceptance of software simulated emergency response planning strategies;

5.2. The Case Study Organisation

NGN is a gas infrastructure provider that supplies the gas storage and distribution facilities for the North of England in the UK. The organisation is responsible for 36,000km of gas mains and service pipes, distributing gas to 2.6 million users. Gas is stored across 47 low pressure gas storage and 2 high pressure storage facilities across 35 sites. The high pressure storage sites are COMAH sites. Responsible to the UK HSE for gas safety matters, NGN are required to develop emergency response plans, for the COMAH sites and test them every 3 years under COMAH legislation. NGN currently apply the tabletop role play method to conduct exercises to test plans.

5.3. The Case Study Research Sample

The research sample includes representatives of the key agencies that attend tabletop role playing exercises, to test emergency response plans developed for NGN’s pipeline assets. Participants include representatives from the Police, Fire and Rescue Service (FRS), Local Authority (LA) and NGN. A range of levels of command within the organisations are represented. Levels of command are denoted by the Gold, Silver, Bronze command structure (Great Britain. Health and Safety Executive, 2010b). Gold denotes a role that operates at a ‘Strategical’ level, Silver refers to a role that operates at a ‘Tactical’ level and Bronze refers to a role that operates at an ‘Operational’ level. Table 3 shows the range of respondents that contribute to the research sample. The participants are all experienced in either developing, facilitating or participating in the tabletop role play exercises used within the case study.

Table 3 Research Sample

Organisation	Level of Command
NGN	Bronze
NGN	Bronze
NGN	Silver
FRS	Silver
Police	Gold/Silver
Police	Silver
LA	Silver
Local Authority	Bronze

The organisational structure of the emergency planning process of the participants is provided in figure 12. The process of developing both onsite and offsite emergency response plans are initiated by the COMAH operator (NGN) and the LA. The knowledge and expertise of other agencies within the emergency planning organisational structure are drawn upon to assist in the development of both the plans and the exercises developed to test those plans. The roles played by the participants in both the emergency planning process and in a live incident are summarised in table 4.

Figure 12 Roles and responsibilities of participants in COMAH emergency response planning strategies developed for high pressure gas piplelines

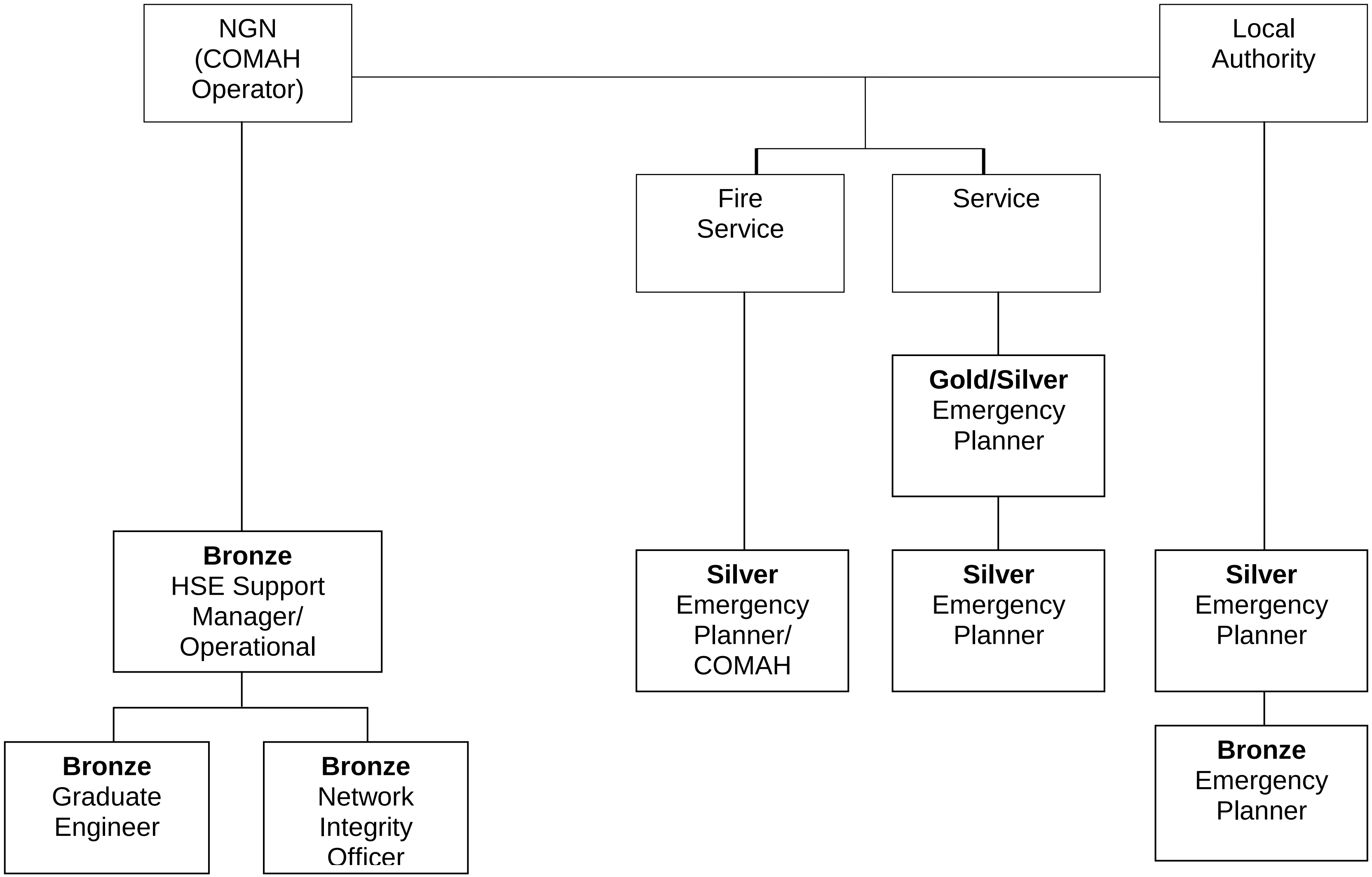


Table 4 Roles and responsibilities of participants in COMAH emergency response planning strategies developed for high pressure gas piplelines

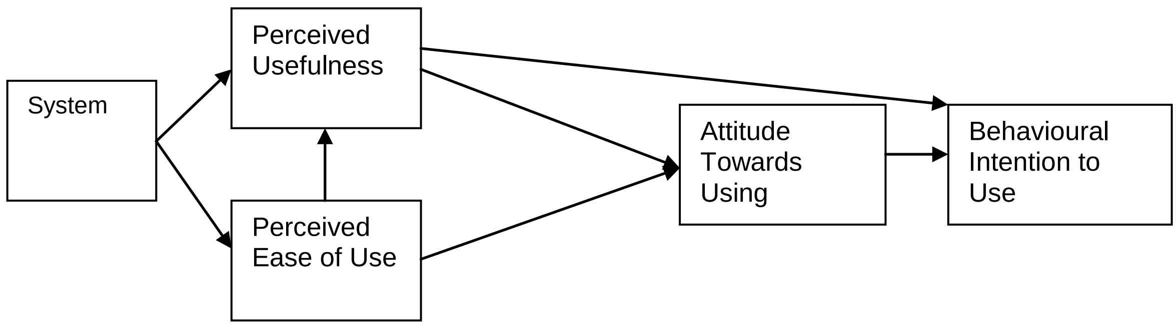
Organisation	Level of Command	Role	Emergency Planning Duties	Duties at a Live Incident
FRS	Silver	Emergency Planner / COMAH officer	Advisor to the emergency planning process offering guidance on how an incident may progress based on experience of live incidents.	Officer in charge of initial response. Perform initial dynamic risk assessments. Determine operational response and commit personnel and resources to deal with an incident. Liaises with Fire Control and other responders.
NGN (COMAH Operator)	Bronze	COMAH Officer / Graduate Engineer	Responsible for making sure that the organisation meets COMAH regulations and other regulations within the pipeline industry.	
NGN (COMAH Operator)	Bronze	Network Integrity Officer	As above.	
NGN (COMAH Operator)	Silver	Health and Safety Executive Support	Developing emergency response planning strategies at both local and national level to coordinate communication between national	Load shedding incident controller ensuring gas is distributed and redirected safely during an incident so repairs can be made to

		Manager / Load Shedding Officer	and local gas transmission organisations.	pipelines. Also operational standby offering advice and guidance to emergency services with regards to gas and pipeline aspects.
Police	Silver	Emergency Planner	Plan and deliver live role play, small scale and tabletop exercises to satisfy COMAH regulations.	Offer technical advice to Silver Commanders in emergency response processes at an incident.
Police	Gold / Silver	Emergency Planner	Plan and deliver exercises for COMAH organisations involving pipeline and civil contingencies	Offer technical advice to both Silver and Gold Commanders at an incident. Coordinate multiple emergency response organisations.
LA	Silver	Senior Emergency Planning Officer	Responsible for deciding every aspect of an exercise in conjunction with emergency service planners and the site operator focusing on COMAH and pipeline safety regulations. Develop and test offsite COMAH pipeline plans. Organise emergency response exercises to test COMAH plans, develop scenarios investigate scenarios from live incidents to use within exercises.	Silver Command providing a link between emergency services and local authority. Assess incidents at a wider level such as keeping things running beyond the actual incident itself. Take the lead role in any recovery phase after an incident.
LA	Bronze	Emergency Planner	Help plan exercises as well as umpire and observe exercises.	Act as a liaison between emergency services and Local Authority.

5.4. The Model Applied to the Case Study Analysis

A deconstructed model of the TAM underpins the research model. The research model includes PU and PEU as the mediated variables of AT. Empirical evidence supports the encompassing of PU and PEU as the combined variables of AT (Szajna, 1996; Taylor and Todd, 1995; Mathieson, 1991). The model is extended to include BI as a result of a combination of the variables PU and AT. Although AT was removed from the TAM2, evidence exists that supports its inclusion as a determinant of BI (Shepers and Wetzels, 2007; Sun and Zhang, 2006; Shih, 2004; Venkatesh and Morris, 2000; Venkatesh, 2000; Venkatesh and Davis, 2000; Davis, 1993; Davis et al., 1989).

Figure 10 Research Model



5.5. The Case Study Research Methods

A number of research methods are applied to satisfy the research objectives 1, 2, 3, 5 and 6 set out in chapter one. The methods employed within this study are required to:

1. Extract and record individual's opinions of the tabletop role playing method for conducting exercises to test emergency response plans;
2. Capture, measure and evaluate individual's perceptions of software simulation to conduct exercises to test emergency response plans;

A general set of questions are recommended by Wolcott (1990, p.32) for organising the initial data capture: "What is going on here? What do people in this setting have to know (individually and collectively) in order to know what they are doing? How are skills and attitudes transmitted and acquired, particularly in the absence of intentional efforts at instruction?". These questions provide the initial framework used to observe and capture information during the case study of tabletop role play exercises to test emergency response plans.

Existing studies support the notion that mixed method approaches combining techniques, improve the quality of the research (Maxwell, 1996; Kaplan and Duchon, 1988; Yin, 1984). Maxwell (1996, p.75) argues that using a mixed methods approach leads to a "better assessment of the validity of the approach" through minimising the likelihood of "biases" or "limitations" that may result as a consequence of using a single method approach. Table 5 (adapted from Maxwell's data planning matrix, 1996, p.82), describes the research questions that the data needs to address and where it can be found.

Table 5 Data Planning Matirix

Item Number	What do I need to know?	Why do I need to know this?	Where can I find the data?
1.	What methods are used for emergency response planning exercises for high pressure gas pipelines.	To satisfy the first objective of the research which is: *to examine and document current practice for emergency response planning exercises, for high pressure gas pipelines*;	- Examination of current exercise methods.
2.	What emergency responder's attitudes, opinions and perceptions are of using software simulation to conduct emergency response exercises.	To satisfy objectives four and six of the research which are: To develop and refine a virtual simulation prototype with which to perform the user evaluation study; To evaluate user acceptance of virtual simulation for testing emergency response planning strategies in the UK gas industry.	- Examine an exercise conducted using software simulation. - Meetings with emergency response experts.

5.5.1. Observation and Interviews

Case studies often combine observation and interview methods for capturing data (Silverman, 1993). Observation allows the researcher to understand meaning and context (Maxwell, 1996). The only way to test an emergency response plan is through an exercise. A case study approach allows us to observe this activity in its natural setting. Interviews can provide additional information about actions and events observed (Maxwell, 1996). Both Silverman (1993) and Maxwell (1996) recommend using a triangulation of observation and interview methods to create a more complete account of the subject being studied.

Silverman (1993) recommends using categories to organise observation notes. The categories provide a framework within which to capture the most important things. Field notes captured during the observation of the tabletop role playing exercises provide the primary source of data for studying existing practice, along with texts provided during the exercises. The categories applied to the case study observation of the tabletop role playing exercises include:

- Participant agencies and roles
- Activities and sequence of activities
- Knowledge required to perform activities
- Details of texts and other materials provided during the exercise

These categories are used to address the questions suggested by Wolcott (1990) table 6 shows how the categories relate to the questions.

Table 6 Categories and Questions for Organising Data Capture

What is going on here?	**What do people in this setting have to know (individually and collectively) in order to know what they are doing?**	**How are skills and attitudes transmitted and acquired, particularly in the absence of intentional efforts at instruction?**
Activities and sequence of activities	Knowledge required to perform activities	Details of texts and other materials provided during the exercise

Silverman (1993) recommends making notes on observations that you see as well as what you hear. Information about the way participants are grouped together, how they react to each other, body language and the movement around or between rooms may all provide information that can be recorded, categorised and analysed. The following categories were added to the list of observational data:

- Location of exercise
- Grouping of participants
- Movement of participants
- Participant behaviour towards other participants

Table 7 extends table 6 to include these categories. These categories form the conceptual framework for the initial observation studies required to answer Wolcott's (1990) preliminary research questions.

Table 7 Categories and Question for Organising Data Capture

What is going on here?	**What do people in this setting have to know (individually and collectively) in order to know what they are doing?**	**How are skills and attitudes transmitted and acquired, particularly in the absence of intentional efforts at instruction?**
Activities and sequence of activities	Knowledge required to perform activities	Details of texts and other materials provided during the exercise
Location of exercise	Grouping of participants	Grouping of participants
Grouping of participants		
Movement of participants		Participant behaviour towards other participants

A set of questions were developed by the researcher to support the gathering of information during observations. The questions were designed to capture the information during observations required to satisfy the categories and the underpinning preliminary research questions recommended by Wolcott (1990). Table 8 shows the questions against the relevant categories of data.

Table 8 Data Categories and Questions for Observation of Tabletop Role Play Exercise

Category	Question
Participant agencies and roles	
	1. Which agencies are participating within the exercise?
	2. Which roles are participating within the exercise?
Location of exercise	
	3. Where was the exercise held?
	4. Was the exercise performed in more than one location or room?
	5. What was the environment like that the exercise was held in?
Grouping of participants	
	6. How were the participants grouped together?
	7. Were all participants included in all aspects of the exercise or did some start or leave at different times?
Movement of participants	
	8. Did the participants move around the environment or did they stay in the same location throughout the exercise?
Activities and sequence of activities	
	9. What activities were performed during the exercise? (list in order of occurrence)
	10. Who participated in each activity? (If all state all otherwise state agency and role)
Knowledge required to perform activities	
	11. What knowledge did participants require in order to participate in an activity?
	12. Was the knowledge specific to that role or agency?
	13. Was any assistance provided for that knowledge such as texts or peer knowledge?
	14. Was the knowledge collective to the group?
Participant behaviour towards other participants	
	15. What are the relationships between the participants? (Are there any levels of command between the different roles, have the participants made acquaintance before the exercise if not how do they introduce themselves)
Details of texts and other materials provided during the exercise	
	16. List any texts that were used to assist in the facilitation of the exercise
	17. Identify whether texts were specific to an agency, role or collective to the group

Interview questions should be used to provide the data required to understand the research questions (Maxwell, 1996). Maxwell (1996, p.58) discusses the importance of using open ended questions to allow the interviewee to answer in ways that are “important to him or her – not to the researcher”. Open ended questions were used to seek opinions from participants on current practice for testing emergency response plans.

5.5.2. Questionnaires

Questionnaires are used during TAM studies to both answer questions required for the TAM analysis and to provide demographic data to support evidence (Ong et al. 2004; Shih, 2004; Van Der Heijden, 2004; Hubona and Burton-Jones, 2003; Venkatesh et al. 2003; Lederer et al., 2000; Chau, 1996). Measures using 7-point Likert-type scales with anchors on strongly agree and strongly disagree are commonly used to capture TAM constructs (Ong et al., 2004; Shih, 2004; Van Der Heijden, 2004; Chau, 1996). The constructs in the research model are measured using items from the TAM, the measures are adapted from previous studies with minor word changes to tailor them to the context. Items for PU, PEU and BI have been adapted from Venkatesh and Davis (2000). AT items have been adapted from Mathieson (1991).

A questionnaire capturing demographic information about participants was employed in this study. Further questions relating to computer experience and opinions of software simulation to conduct emergency response exercises were also included to support data captured during observation and interviews. Participant contact information was captured on the understanding that it would only be used if further information is required that is relevant to this particular study.

The questionnaire contains 15 questions. The first three questions are designed to capture information about the participants' experience in participating in emergency response planning exercises. Questions 4-9 are designed to capture information about how regularly participants use technology and how they use it for work and non-work related activities. Questions 10-15 are specifically designed to capture items relating to PU and AT. See Appendix 16 for the initial questionnaire design. The questionnaire was designed to be distributed at the end of the software simulation prototype demonstration.

5.5.3. Participatory Research

Participatory approaches combine research, education and collective action (Mowbray and Butcher, 2010). The research element is performed by involving members of a community who are viewed as experts that have the knowledge of how things are. A community is defined by Mowbray and Butcher (2010) as a group of people sharing an interest. Participatory approaches are particularly suited to group situations, they encourage discussions and provide a forum for "opinions to be raised, issues being debated, and differences noted" (Mowbray and Butcher, 2010, p.8). Qualitative and in depth information can be captured and used to complement data derived from other sources. Tools and techniques are designed to promote data reliability and validity through triangulation. Education occurs via encouraging participants to share issues and suggest solutions. Actions can be identified from the solutions and a plan made to resolve issues.

The different agencies within the emergency response communities have different responsibilities, priorities and processes at the scene of an incident. Participatory techniques provide inclusive methods that promote a dialogue between agencies that elicit important aspects necessary for the group, to perform their actions as a whole. The participatory methods used in this study serve to capture information to complement the data from the questionnaire, sought to satisfy the constructs in the research model.

5.6. Research Tools and Techniques

The tools and techniques used in participatory approaches are highly visual and inclusive (Mowbray and Butcher, 2010). Caldwell et al. (2003, p.7) note how “many of the methods are visual, and create opportunities for people to participate in discussions at the level that they are comfortable with”. Materials include large sheets of paper, coloured pens, post-it notes and other visual materials. Tools and techniques include mapping, timelines, oral histories, biographies, seasonal and daily calendars, spider or brainstorm diagrams, Venn diagrams, role-play, observation, photographs, video, flowcharts and pie charts (Mowbray and Butcher, 2010). The responses from each of the methods are logged, recorded and collated into different themes and topic areas.

5.6.4. Participatory Research Activities

Coloured Post-it notes, coloured pens and flip chart paper were the materials used to capture information during the comparative evaluation of tabletop role play and the virtual simulation prototype. The pens and Post-it notes provided were a different colour for each participant. This method was applied to allow the researcher to identify the different responses and evaluate them against the participant role and agency to investigate whether any significant patterns emerged in the responses. Responses to questions were recorded on large pieces of flip chart paper during the participatory research activities.

5.6.5. Brainstorming Activities

Brainstorming activities were designed to capture thoughts and opinions on both tabletop role play and the virtual simulation prototype. The following questions were used for the brainstorming sessions:

- What do you think the current tabletop role playing method for testing emergency response plans does well?
- What do you think the current tabletop role playing method for testing emergency response plans doesn’t do well?
- What do you expect of a computer simulation for running an emergency response planning exercise?
- What are your opinions of the computer simulation for running an emergency response planning exercise?

The first three questions were designed to capture information on opinions of tabletop role play and the virtual simulation prototype, prior to the demonstration of the prototype. The fourth question was designed to be asked after the prototype demonstration. Each question was made available on a piece of flip chart paper and participants asked to write their opinions regarding the brainstorming question with their allocated coloured pen. The brainstorming sessions provide an opportunity for the researcher to ask further questions relating to the responses supplied by participants to gather more detailed information.

5.6.6. Timeline Activity

A timeline exercise was designed to capture a timeline of events likely to occur in an incident. A mock incident based on an exercise observed in the case study of a tabletop role play exercise provided the context of the incident for the timeline exercise. The timeline activity served to capture information tabletop role play exercises may not reveal.

5.6.7. Force Field Activity

The force field technique required participants to identify positive and negative feelings towards a topic. Feelings can be identified using smiley faces, a happy smile denotes a positive experience and a sad smile denotes a negative experience. The subject being addressed in the force field activity for this research was the previous experience participants have had with using computing technologies. The force field exercise served to capture information regarding the participants' previous experience with software technologies, to see if there are any patterns in the data that support findings relating to the constructs in the research model.

5.7. The Research Procedure

The individuals that participated in the pilot and main studies were notified that the study would be recorded and how the information would be used. Consent forms were issued to participants obtaining their consent to agree to the use of the data for the purpose of the study. The participants were informed that all results would be published anonymously and their names would not be associated with the data in any publication material. The study was designed to take half a day to complete, refreshments were provided during the study and a comfort break taken between the initial brainstorming sessions and the software simulation demonstration. The entire study was recorded using a voice recorder, the recording was transcribed and coded during the analysis stage.

The data was entered into a research tool called NVivo and analysed. Data drawn from transcripts, questionnaires and brain storming sessions, amounting to a total of 31197 words, was entered into the NVivo database. An iterative process of reading, coding, re-reading and re-coding the material was performed to identify key findings and highlight relations between the data and the TAM. Coding is the main categorisation strategy in qualitative research (Maxwell, 1996). The purpose of coding data is to identify categories within which to organise the data. Once organised into categories, comparisons can be made in the data to facilitate the development of theoretical concepts (Maxwell, 1996). An deductive approach to developing categories and themes to organise the data has been applied to this study.

5.8. Conducting a Pilot Study

Pilot studies are commonly used to test research methods and processes where the time and availability of participants are limited (Bowman et al., 2005; Lederer et al., 2000; Maxwell, 1996). Using a pilot study allows the researcher to test the process of capturing the data without the need for all participants to be present. A pilot study also provides an opportunity to test the usability and software requirements are met (Bowman et al., 2005). Teijlingen and Hundley (2001) recommend the use of pilot studies to highlight areas where the study may fail. The pilot study was used to highlight any amendments required to the software before the main study evaluation was performed.

A pilot study may be used to test whether the information required by the research objectives can be gathered. A pilot study was performed to test the process of conducting the research experiment and the methods. The participants for the pilot study included the researcher, an expert from the gas industry who has knowledge and experience of emergency response exercises to test plans and a participatory research facilitator. The role of the researcher was to ask questions regarding the responses that are submitted during the study, test methods and demonstrate the software. The facilitator served to ensure that the data capture process remained inclusive of all participants. The pilot study was recorded and transcribed, the details of the pilot study can be found in Chapter 6 -Section 6.3.

5.9. The Research Methodology

This chapter has presented a research methodology which uses a deductive approach whilst applying a triangulation of deductive methods for evaluating software simulation for testing emergency response planning strategies. A case study of existing methods and practice for conducting emergency response exercises informed the design and development of the software simulation prototype. The case studies and the development of the prototype are discussed in Chapter 7. A deconstructed version of the TAM provides the theoretical framework that guides the development of the research instruments used to measure participants’ perceptions. The purpose of the study is not to create new learning methods, rather to create existing methods in a new environment. A combination of interviews, questionnaires, observation and participatory research techniques, are the methods used to capture data regarding current emergency response planning methods and the proposed software simulation. The data planning matrix in table 5 is extended in table 9 to include a column for the kind of data required to answer the research questions.

Table 9 Data Planning Matrix

Item Number	**What do I need to know?**	**Why do I need to know this?**	**What kind of data will answer the questions?**	**Where can I find the data?**
1.	What methods are used for emergency response planning exercises for high pressure gas pipelines.	To satisfy the first objective of the research which is: *to examine and document current practice for emergency response planning exercises, for high pressure gas pipelines*;	- Observation of traditional tabletop exercises. - Interviews with emergency planning representatives and participants.	- Examination of current exercise methods.
2.	What emergency responder's attitudes, opinions and perceptions are of using software simulation to conduct emergency response exercises	To satisfy objectives four and six of the research which are: *To develop and refine a virtual simulation prototype, with that of traditional methods for testing emergency response planning strategies;* and *to evaluate user acceptance of virtual simulation for testing emergency response planning strategies in the UK gas industry.*	- Observation of software simulation environment. - Data gathered through brain storming sessions. - Questionnaires. - Notes from transcripts recorded during observation of software simulation.	- At an exercise conducted using software simulation. - Meetings with emergency response experts.

Table 10 demonstrates the methods discussed and where they will be used to gather the data required for the study.

Table 10 Use of Research Methods

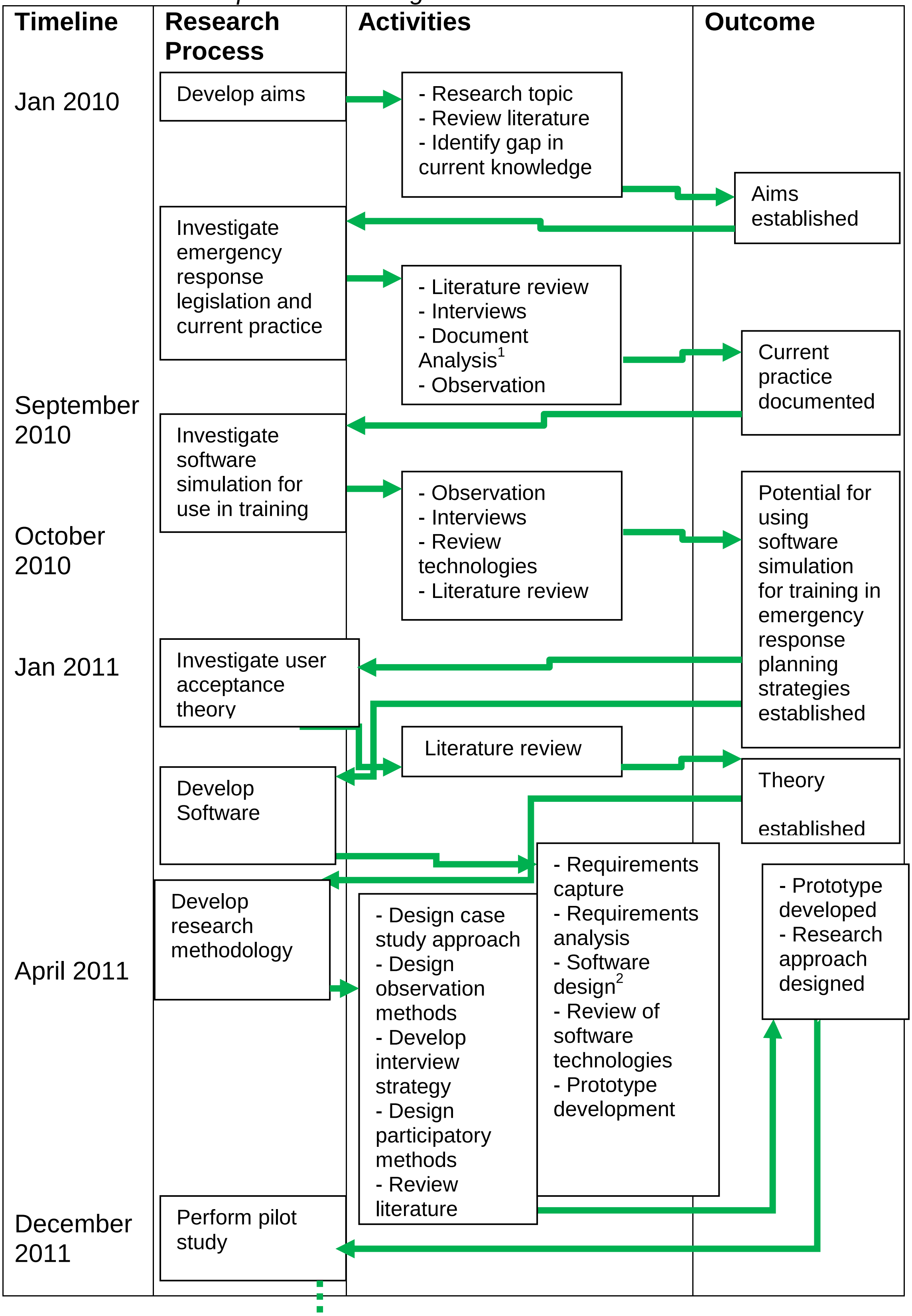
Method	**Case Study**	**Pilot Study**	**Comparative Evaluation**
Observation	Yes	Yes	Yes
Interviews	Yes		
Audio Recording	Yes	Yes	Yes
Questionnaire		Yes	Yes
Participatory research:			
Brainstorming		Yes	Yes
Force Field		Yes	Yes
Timeline		Yes	Yes

Two emergency response planning exercises that used the tabletop role playing approach were observed. The details of the observations are documented in Chapter 6. Interviews performed during the case study provide information about current emergency response planning practice. Semi-structured interviews were designed to support the information gathered during the observation of the exercises. The participants interviewed included employees from NGN and other agencies experienced in attending exercises to test NGN's emergency response plans. These agencies included representatives from the Police, Fire and Rescue Service, NHS and Local Authority. Subjective data such as opinions, comments, and preferences were gathered during demonstrations and throughout observations of the comparative evaluation.

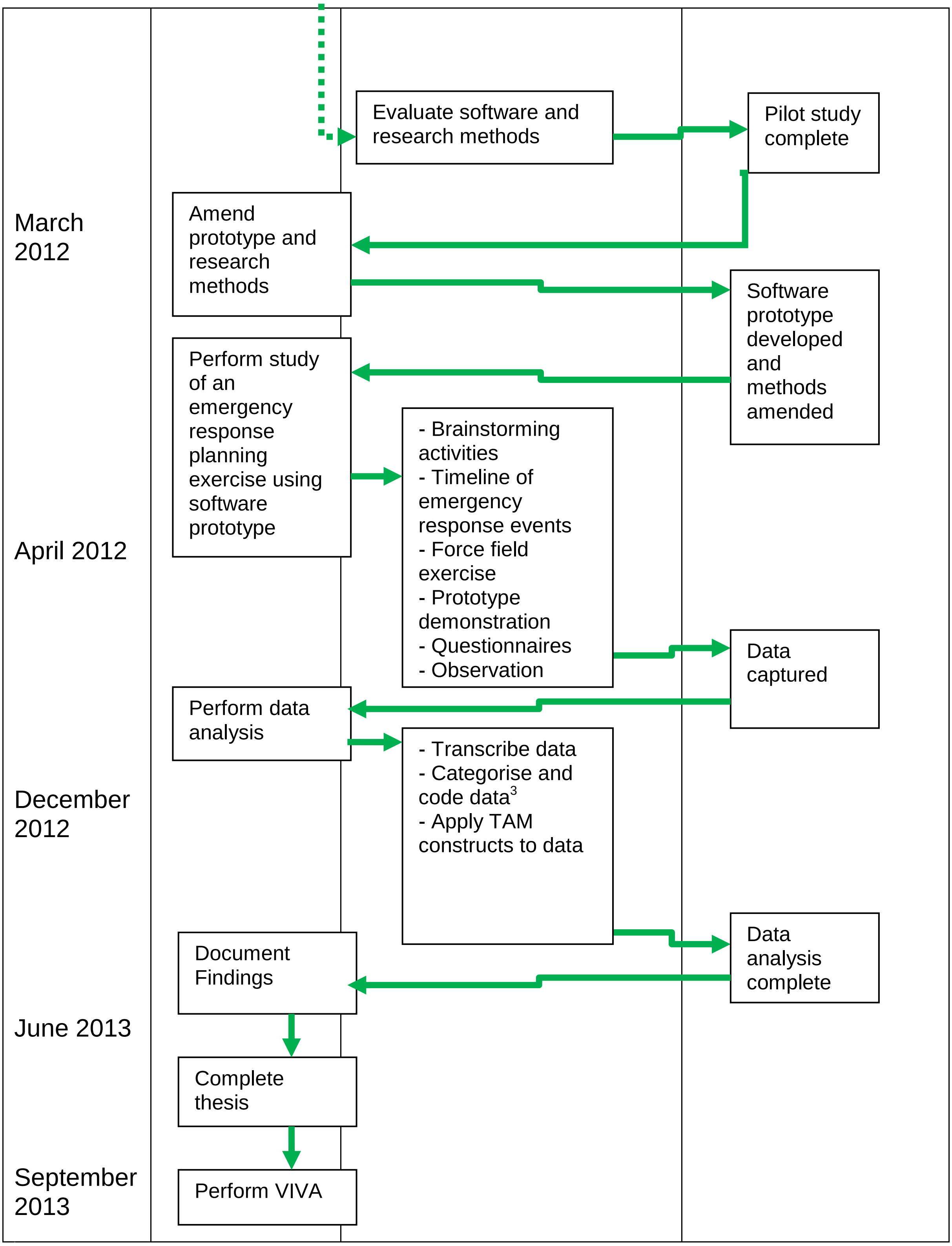
All recordings conducted during interviews were recorded with a voice recorder. Permission was sought but not granted to record instances of exercises that applied the current practice of tabletop role playing methods. Permission to record the pilot and main study evaluation of the software simulation prototype to conduct exercises using a voice recorder was granted. Field notes have been used to complement audio recordings and capture data not picked up with audio recordings.

The virtual simulation prototype provides a tool to investigate and to assist in the evaluation of software simulation for testing emergency response planning strategies. The research sample consisted of a group of participants representative of emergency response planning strategy participants. The prototype served to investigate and evaluate what the participants think software simulation can bring to the emergency response planning process. A pilot study served to validate the process of conducting the research experiment and the methods used. A combination of techniques including coding and categorisation of the data were applied to evaluating the data using the research model. The research phases and stages are shown within table 11. The approach used to develop the prototype is discussed in the next chapter.

Table 11 Research phases and stages



[1] Example emergency response documents from case study can be found in Appendix 5.
[2] The design documentation for the software simulation prototype can be found in Appendix 6.



[3] Data from the evaluation can be found in Appendices 9-18.

Chapter 6 The Prototype Development and the Pilot Study

The development of the virtual simulation prototype using the workflow stages from the Unified Process (UP) is presented, Appendix 5 describes the UP. A case study of existing emergency response planning strategies is presented. Phase 1 of the requirements capture process sought to identify the key features of the system and to understand the potential users and their needs. The data captured during the case study informed the requirements capture process of Phase 1. Phase 2 of the requirements capture process describes the refinements that were made to the requirements. The structure of the prototype architecture is described and the design of each tier within that structure is documented. The prototype design documentation can be found in Appendix 6.

An initial prototyping phase was conducted to test out requirements, information flows and layout. The iterative processes of the design review and refinement stages are described. A pilot study was performed to test both the prototype and the feasibility of the data capture methods. The methods and process of conducting the pilot study are presented. The lessons learned during the pilot study that informed changes to the design of both the prototype and the design of the research methods are discussed.

6.1. Development of the Prototype

The case study has been drawn from the researcher's naturalistic observation of existing emergency response strategies practice (Frey et al., 1999). The process of developing the virtual simulation prototype was conducted in parallel to the case study research, this is now presented.

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6.1.1. A Case Study of Current Practice

Exercise Cornerstone and Exercise Dragon are the names of two exercises that applied the current practice of tabletop role play for testing emergency response plans. These exercises were conducted by NGN and were observed during the case study. Both exercises were developed collaboratively between NGN and the corresponding LA to test offsite emergency response plans for two existing COMAH gas storage sites. The exercises consisted of a series of possible scenarios that may result in an incident of failure at the sites the plans related to. The exercises were designed to require a response from multiple agencies. Representatives of agencies likely to respond to the incident chosen for the exercises were invited to participate. Both exercises were completed over the course of a single day. In both cases the exercise was initiated and facilitated by a member of the HSE. A gas expert from NGN was called upon at regular intervals to provide feedback and recommendations on decisions made regarding the exercise.

In each exercise the facilitator began by introducing the purpose and format of the exercise. Subsequently the facilitator presented the participants with the first scenario. The agencies were then encouraged to engage in the exercise as if they were responding to a live incident. Both exercises were time constrained and the facilitator requested regular progress updates throughout the exercises. Participants were given copies of the emergency response plan to be tested. Information such as geographical data, gas pipeline data and local community details were also supplied. Further information such as wind speed, weather data or travel information could be obtained throughout the course of the exercise upon request.

During the exercises interjects (figure 13) were submitted to participants with the intention of imitating unforeseen events at the incident. An interject, is a piece of paper, supplied by the exercise facilitator, that contains information about something that might hypothetically happen during the course of the incident. An interject, is normally given to a single group of participants representative of an agency, rather than to the whole group. It was the responsibility of the group to decide how to disseminate the information regarding the interject, to the rest of the participants and to make the final decision on how to respond to it. An example interject given in Exercise Dragon included the description of a worker in a compound near to the incident, about to leave the safety of his cabin, he heard sirens and was not sure whether or not he was safe to leave. The group had to decide how to respond to that event.

Figure 13 Sample Interject

To: Northern Gas Networks	**From:** Sabic
Issued at:	23rd June 2012 9:30pm
Reason for Interject:	
One of our workers is onsite at the Billington office, they are held up in their cabin and have heard sirens. They can see police and fire representatives over at the well head and are wondering if it is safe to leave the cabin or if they should stay inside and await further instruction.	

At the end of each exercise the facilitator held a debriefing to discuss the responses from participants. During the discussion of responses the NGN expert responsible for contributing to the development of the plan, presented facts about the scenario participants may not have been aware of. Facts such as details about exclusion zones, the impact an explosion may pose and details of likely response times by NGN were provided. The facilitator recorded the exercise outcomes and the activities completed. These records were used to conduct an action review meeting, one of which was held after each exercise was completed. The outcomes of the action review meeting were compiled into a report by the facilitator and NGN expert. The report was submitted to the HSE and serves as evidence that the organisation had performed the testing of the plan, as required by both COMAH and PSR legislation.

Exercise Cornerstone and Exercise Dragon were both observed by the researcher and hand written notes were taken to record the activities undertaken during the observations. Copies of materials issued at the exercises were made available to the researcher for further use. These documents contained sensitive pipeline data including geographical maps of areas displaying the location of the incident, interject forms and written descriptions of the incident. The geographical maps had exclusion zones printed on them and handwritten notes that were added to the maps by participants during the exercise. Maps detailing pipeline data such as location and pressure were also supplied. Blank examples of interject forms were provided and the researcher gathered notes on interjects that were used throughout the exercises. Upon completion of the exercises, the researcher was given an opportunity to ask questions regarding the exercise and the techniques used.

One to one interviews with the researcher and participants were conducted during the exercise. The interviews took place at natural breaks within the exercises. Further interviews were conducted independently with employees of the COMAH organisation. Some interviews were recorded and transcribed and some were recorded with hand written notes. The interviews conducted with the NGN employees served to provide the researcher with further detail regarding the current process and methods used for emergency planning response strategies within the organisation. Exercise Cornerstone and Exercise Dragon are described in more detail along with the findings that resulted from the case study.

6.1.2. Exercise Cornerstone

Exercise Cornerstone was a tabletop role play exercise conducted to test one of NGNs offsite plans. The exercise was split into 3 parts, 3 different teams had 3 different scenarios that were run simultaneously during a single exercise. Each of the 3 exercise teams consisted of 5 participants plus 1 facilitator. The participants that made up the groups included representatives from the Police, Fire and Rescue Service (FRS), NGN and the Local Authority (LA). Each group had a Police representative assigned as the syndicate leader. This is representative of how the Police act as command and control liaison in a live incident. 3 different scenarios were provided in the exercises, each based on a different location within the North East of England. The participants were assigned to the locations that the agencies they represented were responsible for.

In addition to the 3 teams who were participating in the exercises, a further 3 groups attended the exercise, a group of facilitators and specialists, a group of media representatives and a group of specialist observers. Each group had a table designated to them and each participant was shown to their relevant table upon arrival. All groups were situated in the same room throughout the exercise. Each group and the exercises performed are described in more detail.

Group 1: Facilitators and Support

The facilitators and support group consisted of 9 participants: 1 exercise coordinator, 4 virtual Silver and Gold command representatives, 3 exercise group facilitators and an expert from NGN. The exercise coordinator facilitated the overall exercise, they introduced the purpose of the exercise and explained how the scenarios were to be conducted. Each exercise group had an individual group facilitator assigned to their group. The group facilitators were all representatives of Tyne and Wear Emergency Planning Unit and had contributed to the planning of the exercise scenarios. The group facilitators were responsible for answering generic questions regarding the tasks and ensuring that groups adhered to timescales.

Four participants played the role of virtual Silver and Gold command. A representative from the FRS, two from the Police and one from the NHS assumed these roles. Whilst not designated to specific groups, the virtual Silver and Gold command were able to walk between groups offering advice from a tactical and strategical level from their agency perspectives. The final member of this group was an expert from NGN. The expert was called upon throughout the exercises to offer comments on the recommendations made by the groups during the exercise.

Group 2: Media

The media group was made up of 4 participants, 2 were representatives from the Police and 2 from NGN. The role of the media group was to request information during the exercises that would come from media organisations in a live event. The specialists and observers group was made up of 3 participants, the researcher, an exercise planner from the FRS and an observer from the LA. The role of each of these persons was described to the rest of the participants. Each of the persons within this group joined one of the 3 main exercise groups.

Table 12 describes the agencies and the type of participants that were represented at the exercise:

Table 12 Exercise Cornerstone Participants

Organisation	**Facilitator**	**Gold Command**	**Silver Command**	**Bronze Command**	**Media**	**Observer**
NGN	1		1	3	2	
LA	1			2		1
FRS		1		3		1
NHS			1	3		
Police		1	1	3	2	
Tyne and Wear Emergency Planning Unit						
Other	3 Plus 1 coordinator					

Each scenario was set in a different geographical location, one at Newcastle upon Tyne, one in Gateshead and one in Sunderland. Each group was given a set of instructions regarding their role and a generic background to the exercise that applied to all three scenarios. The background described the event of a contract digger striking a high pressure gas pipeline. The exercise time was set the same for all three scenarios. Each group was given individual details of their scenarios printed on an A3 sheet of paper. The scenario details described the incident location, the initial leak, the resulting impact, the consequences of an escalating leak and what would happen in the event of an ignited escape.

Each scenario had 5 tasks assigned to it. Each task was time constrained and numbered in order of the sequence they would occur in a live incident. The first task had incident specific information assigned to it and a series of generic events likely to occur as a result of the incident such as: '*where would the control points be established'*. Each group was given scenario specific materials such as geographical maps and pipeline data relevant to their incident. The scenario tasks were printed on one half of an A3 sheet of paper, the other half was left blank for the responses to each event. The group facilitator recorded the responses of the group on the scenario task sheet. The other four tasks were generic and applied to each incident scenario.

Upon completion of each task the exercise coordinator asked each group what their actions would be in response to the tasks and subsequent events that occurred. After each group response the COMAH organisation expert provided technical information with regards to the scenario, such as gas dispersion progression and recommended evacuation distances. Once all three groups had provided a response to the task, the next time constrained task began. This process was repeated until all 5 tasks were complete.

A lunch interval took place upon completion of all 5 tasks. During the lunch interval the facilitators, exercise coordinator and NGN expert discussed the main outcomes of the exercise. The discussion was used to identify any changes required to individual agency operations procedures and to the emergency response plan as a result of the responses made during the exercise. After the lunch break all participants took part in a discussion which was lead by the exercise coordinator to discuss the main points highlighted during the lunch break, this was referred to as the '*Exercise Hot Wash Up'*. At the end of the exercise the participants were asked to complete an evaluation form which was developed to monitor and evaluate the quality of the exercise, to inform future exercise development.

6.1.3. Exercise Dragon

Exercise Dragon was based on a single scenario. All exercise participants were taken to a room and offered refreshments upon arriving. Table 13 describes the agencies and the type of participants that were represented at the exercise:

Table 13 Exercise Dragon Participants

Organisation	**Facilitator**	**Silver Command**	**Bronze Command**	**Observer**
NGN	1		3	1
LA	1	1		
FRS		1	2	1
NHS			2	
Police		1	1	1

As the exercise commenced the FRS participants were taken into the room where the main exercise was to held. The FRS participants were asked to listen to a 999 telephone call which described the incident from the point of view of someone at the scene of the incident. They were then asked what their next action would be, the LA facilitator recorded the response using handwritten notes. The FRS participants were asked to take a seat at a large table situated in the middle of the room. Further information regarding the incident was presented in a document that the FRS participants were encouraged to read to inform subsequent decisions to be made. The FRS participants were able to request information such as wind speed and weather data from the LA facilitator.

The NHS participants were then asked to join the room and listen to the 999 call describing the incident. The NHS participants were also shown a projected image from a PowerPoint slide of a mock up of the incident (Appendix 4). The NHS participants were allowed to ask the FRS participants questions regarding the incident. This action was intended to simulate the NHS responders arriving at the scene of an incident, where the FRS were the first responders on the scene. The NHS representatives were then asked to treat the NGN facilitator as one of the injured parties described in the 999 call. A written record of the discussion held between the NHS responders and NGN facilitator was made by the exercise facilitator. The NHS responders were then asked to sit down at the main table and the Police were asked to enter the room.

The Police asked the FRS for an incident debrief, the Police then also asked the NHS for an incident debrief regarding the casualties. The FRS requested some information which required the presence of the LA representative. The LA representative was asked to join the room. Further discussions were held between the exercise participants, then the Police declared the incident as a major incident. The NGN participants were then asked to join the exercise and entered the room. The NGN participants were debriefed by the Police, all participants sat round the main table and were given time to read the printed scenario information and ask questions regarding the incident.

The NGN participants requested further details regarding pipeline data. This was provided and the NGN participants were asked to take their discussion to a separate table located at the side of the room. Each agency was asked to continue their discussions between their agency groups to decide what actions they would take next. During these discussions the LA facilitator presented interjects to some of the agency groups. The discussions continued until the incident was declared under control.

Once the incident was declared under control, the exercise paused for a lunch break. During the lunch break the LA facilitator, NGN facilitator and the Police and FRS observers all discussed the main points arising from the exercise. After the lunch break a debriefing session took place, all participants were asked to submit their opinions regarding the points they had learnt on Post-it notes. The Post-it notes were all placed on a large board and a group discussion was held to discuss the points raised. The LA and NGN facilitators created a report highlighting the main outcomes of the exercise which was submitted to the HSE.

6.1.4. Phase 1: Requirements Capture

An initial set of requirements defining the activities required of the prototype were developed through a combination of observation and interview techniques during the case study. Emergency response exercise experts were interviewed during the case study to gather further detailed information. The high level requirements identified during Phase 1 of the requirements capture process are listed in Appendix 6: Table 30 Prototype Requirements.

A review of the initial requirements between the researcher and a system expert from NGN revealed that an exercise's content is confidential. As such any content should only be accessible by exercise facilitators or participants. To keep content secure, an authenticated log in facility is required to access the system. Appendix 6: Table 30 has been extended to include an authenticated secure log in as shown in Appendix 6: Table 31 Prototype Requirements.

Two types of user account were required of the system: an administrator and a user account. The administrator account includes functionality such as adding an organisation or role to the system. The ability to allow multiple users to participate within a single exercise was also highlighted as a requirement of the system. The facility to add an exercise to the system was suggested as a desired goal of the system, but it was agreed it was not required for the purpose of the prototype. Each requirement is documented in more detail in a set of use case diagrams and use case specifications (Appendix 6). Appendix 6: Use case 1 defines a high level view of the system requirements, while Appendix 6: Use Case 2 and Appendix 6: Use Case 3 provide more detailed descriptions of those requirements.

An investigation into potential users of the system and their needs was performed. The next section describes the information gathered about the users. The use cases were refined in response to the information gathered about user needs and are discussed in Phase 2 of this chapter.

6.1.5. Potential System Users

Emergency response exercise experts were interviewed to identify typical user profiles of potential system users. The interviews were conducted as informal discussions where the researcher prompted the experts for information regarding job roles, activities and the use of software to perform activities within their everyday roles. Table 13 offers an initial overview as to the software the different domain experts are familiar with using.

Table 14 Overview of software use by domain experts

	Police	Fire Rescue Service	NHS	Local Authority	Gas infrastructure provider
Microsoft Office	Yes	Some	Some	Yes	Some
GPS	Yes	Yes	Yes	Yes	Yes
Job Incident Reporting Software	Yes	Yes	Yes	No	Yes
Job Specific Software	No	No	No	Yes	Yes
Text messaging	Yes	Yes	Yes	Yes	Yes
Email	Yes	Yes	Yes	Yes	Yes
Instant Messaging Software	Yes	Yes	Yes	Yes	Yes
Simulation Software	Yes	Yes	No	No	No

An initial study of the domain expert sample to be researched reveals the following information about the general experience of using software within their working environment. Participants from the LA are office based and are familiar with using Microsoft Office Applications along with some internal custom database software. Participants from the FRS, NHS and Police services use software for a variety of uses depending on their role. Employees from these agencies who are desk based use a range of Microsoft Office software in addition to using specific incident reporting software and Global Positioning System (GPS) technology. Participants from these agencies who are patrol or vehicle based use onboard equipment such as GPS and traffic reporting equipment.

Employees from the COMAH organisation use custom laptops that connect to hardware systems within their vehicles. Custom software is used which includes systems that provide geographical maps, gas pipeline network maps, a job incident notification and logging database, an internal instant messaging system, timesheet software and a pipeline parts catalogue. Some representatives from the Police and Fire and Rescue Services had experience in using the Hydra Immersive Simulation System, discussed in Chapter 3.4, to train for responding to fire related incidents. A preliminary review of potential users revealed that typical users of the proposed system are familiar with using a wide range of generic and job specific software. These findings were considered when assessing the technologies and platforms to implement the prototype with.

6.1.6. Comparing Live Incidents to Role Play

Four emergency response experts were interviewed at the tabletop role playing exercise, Exercise Cornerstone, interview transcripts are available in Appendix 8. The interviews highlight three elements of the tabletop role play that differ from a live incident:

1. The opportunity to discuss approaches with other agencies;
2. Following own agency change of command;
3. Response time for actions.

The opportunity to allow agencies to build communication relationships was highlighted as one of the benefits of tabletop role play by the NGN system expert. Tabletop role play not only serves to test plans but also procedures (Wilson, 2000). Another advantage highlighted with the tabletop role playing environment was that it provided a forum where agencies could discuss approaches and highlight issues with standard procedures within agencies. Where emergency responders have had the opportunity to develop relationships prior to an incident, access points for communication with agencies are developed. Chain of command processes between agencies are highlighted as issues recognised within literature (Quarentelli, 1988). Creating relationships through training exercises establishes command procedures prior to an incident and is shown to improve incident communication processed between agencies (Quarentelli, 1988). Having a method within the simulation that enables communication between users is a desired feature of the system. Appendix 6:Table 31 is extended to include the ability to communicate as shown in Appendix 6: Table 32 Prototype Requirements.

The Chief Police Inspector and both NGN Representatives highlight the ability to create an environment which increases the pressure to make decisions where risk is involved as something tabletop role play is lacking. When questioned further about recreating elements of stress to simulate the adrenalin feeling or feeling of risk, the respondents stated that stress was not a factor of their role. They viewed the activities they encountered as part of their role as work tasks and therefore did not see stress as a contributing factor to risk. Having an element of risk or something that can replicate urgency is a desirable feature of the software. The use of sound and visual cues to increase feelings of presence and reality are a requirement of the system. The requirements were extended further to include implementing visual and audio cues and providing an element of urgency (Appendix 6: Table 33).

6.1.7. Phase 2: Requirements Capture

The initial requirements were reviewed by the system experts at NGN and the researcher. The review highlighted some areas for further refinement to the requirements, these were:

1. The administrator would simulate the role of the exercise facilitator and begin the exercise, removing the need for an Exercise Narrator role within the system.
2. The Administrator would initiate the exercise once all the required users were logged on and ready to begin. An exercise could only begin once all users participating in an exercise were logged into the system.
3. The storing of personal details of participants within the database was discussed. It was specified that participant details were confidential and should not be stored within the database.
4. Generic roles should be assigned to agencies that represent the level of command a role represents. The authentication details should be designed to reflect the role of the group. For example, if a group is made up of representatives from the Police and the highest ranking Police officer is of the Silver command level, the role that group assumes within the system would be Police Silver. Similarly if a group of representatives from a gas infrastructure provider were participating at an operational level, their group would log into the system with authentication details that represent Gas Bronze. Table 15 lists the agencies and level of command for the role required by the system. The system has been developed so that additional agencies or roles may be catered for in the future.

5. The role of exercise narrator is no longer required within the system. Scenarios are to be added as a resource such as text, image, video or 3D model. The scenario resources are to be used to describe the narrative of the exercise. The facilitator will initiate the exercise and the scenario resources.

6. The on-site and off-site controller roles are not required within the system. These roles will be assumed by different participants during the exercise. The detail of the activities they perform should be entered as responses to the incident by the users that assume these roles.

7. The administrator of the system would discuss the outcomes of the exercise with the users or participants in a post exercise debrief. The prototype should demonstrate that exercise details can be extracted from the system but only by an Administrator and not a User.

Table 15 System Roles

Fire and Rescue	**Police**	**Ambulance**	**Gas**	**Local Authority**
Bronze	Bronze	Bronze	Bronze	Bronze
Bronze	Bronze	Bronze	Bronze	Bronze
Silver	Silver	Silver	Silver	Silver
Silver	Silver	Silver	Silver	Silver
Gold	Gold	Gold	Gold	Gold
			Trainer	
			Trainer	
			Trainer	

The Use Cases were amended to include these refinements along with the additional requirements highlighted in Appendix 6: Table 33. The amended Use Cases can be found in Appendix 6: Use Case 1.1, Appendix 6: Use Case 2.1, Appendix 6: Use Case 2.3. The requirements have been captured and refined, the next stage in the prototype development was to design the structure and interfaces of the system and to identify the technologies to be used with which to implement the design. The design stage is discussed in further detail in Phase 3.

6.1.8. Phase 3: Design

6.1.8.1. Architectural Design of the System

A requirement of the system was to provide Multi-user access. A system that is accessible from multiple devices requires a client-server model approach. A client-server model is an approach where one or more devices act as a client that accesses the system that resides on a server. Figure 14 provides a visual representation of a client-server model.

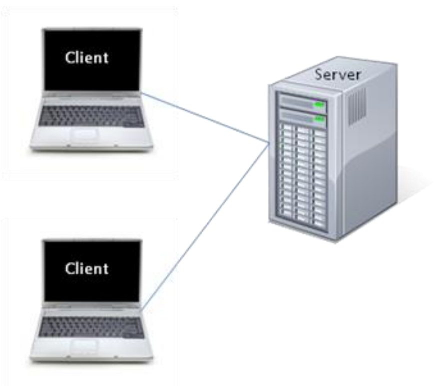

Figure 14 Client-Server Model

A client-server model is commonly developed with an n-tier architecture where n is the number of tiers or levels within the system. The system will use a 3-tier architecture composed of the user interface layer, the business logic layer and the data layer. Figure 15 demonstrates the design of software that employs 3-teir architecture and the components it consists of.

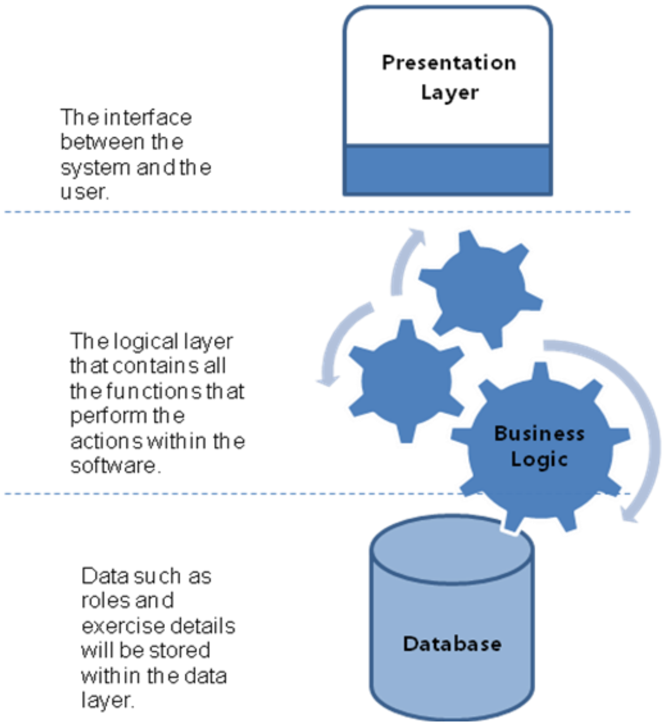

Figure 15 3-tier Software Architecture

The design of each level within the model is described in more detail.

6.1.8.2. The Database Design

The database is responsible for storing all data. The data for the system developed for this research includes information such as roles, organisations, exercises and exercise resources. The structure of the database is designed from the classes derived from the use cases. Appendix 6: Figure 26 shows the structure of the classes required to be implemented within the database, the attributes each class has and the relationships between the classes.

6.1.8.3. The Business Logic

The business logic contains the functionality required to perform the processes between the presentation layer and the data. Appendix 6: Figure 27 shows the design of the business classes and the methods contained within them. The ExerciseController and UserController classes act as the interface between the business layer and the data. The ExerciseServer class acts as the interface between the business layer and the presentation layer.

6.1.8.4. The Presentation Layer Classes

The presentation layer contains the functionality that allows the user to interact with the UI and perform actions within the software. This section demonstrates both the design of the presentation logic and the aesthetic design process. Appendix 6: Figure 28 demonstrates the methods defined in the boundary classes that represent the presentation layer of the design. The ExerciseUI class shows the methods that perform the functions required when the user interacts with the UI. The ServerProxy class acts as an interface between the ExerciseUI class and the business layer.

6.1.8.5. Prototyping the User Interface

Once an initial set of requirements were defined a combination of software and paper prototyping techniques were performed to test out elements of the navigational design. A set of wireframes were developed in PowerPoint and used to demonstrate layout and structure of the screen (see Appendix 7 for wireframes). PowerPoint software was chosen so that the researcher could demonstrate information flows through mimicking clicking on certain elements of the PowerPoint slide. The purpose of the prototyping exercise was to:

1. identify how the information flowed through the system;

2. identify any specific requirements of the system not yet discussed;

3. discuss details of possible task activities that could be integrated for testing purposes;

4. highlight any issues with the proposed approach.

Feedback from this initial prototyping phase confirmed that the requirements of the information flows throughout the system had been understood. Visual indication of the resources required to support exercises, such as maps, pipeline, images and other information relevant to an exercise were demonstrated.

6.1.9. Evaluation of the Prototype Design

The initial prototyping session highlighted issues with how the software would be stored, where it would be stored and how it would be supported and maintained. The option to store the software on a server hosted remotely was discussed and this solution was thought to bring issues regarding ongoing maintenance and support. Hosting the software on a server at the COMAH organisation was also discussed but again, issues surrounding cost and ongoing support and maintenance were raised by the COMAH organisation representative. A solution was required that could be stored without being hosted remotely became both a functional and technological requirement of the system.

The prototyping exercise prompted discussion of how the software would be accessed. Concerns with allowing access via the internet by participants were raised, as was the availability of networking facilities at the exercise location. A solution that overcame the reliance on a venue’s networking facilities was required. The physical aspect of how the exercise would be run and how participants would interact with that software were considered. Projecting the simulation from a laptop via an overhead projector was one option suggested, whilst having groups of users assigned to devices that allowed them to interact with the simulation. An advantage of the current tabletop role playing solution is that it encourages participants from different agencies to communicate. A solution containing groups sat around devices prompted concerns over agencies isolating themselves into separate groups by agency, thus discouraging groups from communicating. Further research to investigate possible solutions to address these issues was considered when investigating the software platform and technologies to use.

6.1.10. Identifying the Software Platform and Technology

The system requires a technological solution that supports client-server architecture. The solution should be able to run on an independent secure network. The solution should provide audio and visual representations of exercise details. Interactive web technologies, gaming software and existing training systems were all examined during the search for a technology that satisfied the requirements of the system. Technology that supports the development of a CVE as recommended by Churchill and Snowdon (1998) incorporating both an interactive communication interface and an interactive tool (Riva, 1999; Stone, 1992) was required by the system. The technology was required to provide the facility to test out different scenarios to improve responders understanding of an incident and increase their preparedness (Jain and Mclean, 2005; Jain and Mclean, 2003; Simpson, 2001). The ability to represent visual cues to reduce the burden of the imagination on the user to imagine the scene was a requirement of the system (BinSubaih, 2005).

6.1.11. Existing Software Simulation Technology

The Hydra Immersive Simulation System is an interactive application currently used by the Police and FRS that allows incidents to be simulated. Whilst the system is portable to some extent the machinery is large and difficult for one person to transport from venue to venue. Each venue requires the pods and the networking technology available in order to install and run an exercise on the Hydra system. A portable solution was required that allowed a facilitator to transport the equipment easily from venue to venue that was supported on its own network and not reliant on a venues' networking technologies. This made the Hydra Immersive software an unsuitable solution for the required system.

6.1.12. Games Engine Technology

Gaming technologies provide a resource that supports client-server architecture that allow multiple devices to access, share and interact with data on a server. For Example Microsoft XNA Game Studio, provides a development environment within which applications can be created for Windows, Windows Phone, and Xbox 360 (Microsoft, 2012). XNA can use games engines to perform physics and rendering functions. Whilst the technology has the capability to render 3D models and animate them, specialist knowledge for developing 3D models is required. As the research of the literature in Chapter 3 revealed, the development of realistic, real-time models can incur high development costs (Smith and Carter, 2010).

Recommendations from the literature review include balancing the needs of the system against the available resources (Smith and Carter, 2010; Smith and Duke, 2000). A requirement of the system developed for this research was that administrators of the system should be able to add and edit exercise data. A solution that allowed users to add data that doesn't require knowledge of 3D model development was required. Whilst a desire of the system may be to display 3D models and 3D animations to display visual cues during the exercise, the ability to render those models as a dynamic model is not essential.

The exercises are developed to test the plan and the processes of applying that plan, not to assess how a participant would perform an action such as putting a fire out. Training to deal with physical aspects of the emergency response is outside the scope of the exercises designed to test emergency response plans. Visual and audio cues can be used to enhance the setting of the scene of an incident. Initial discussions with potential users revealed that the system should provide a facility to view the incident in some shape or form, but not to interact with the scene directly. As no interaction with the models was required, there was no further need to research the use of games engines.

6.1.13. Windows Presentation Foundation and Windows Communication Foundation

The Windows Presentation Foundation (WPF) is a programming model developed by Microsoft that can be used to build client user experiences through the user interface, media and documents (Microsoft, 2012a). WPF has capabilities for rendering both 2D and 3D media, making it a flexible solution for using both types of media should they be available. Windows Communication Foundation (WCF) is a framework that service-oriented applications can be built on (Microsoft, 2012b). A service-oriented application allows messages to be passed from the client to the server. Messages can be encrypted to make them secure and protect privacy as they pass across a network (Microsoft, 2012b).

A test project was developed to prove the concept of using WPF and WCF technologies, as a possible solution for the system. A UI was created using WPF technologies that displayed a 3D animation. The WPF application was installed on two laptops, one of which acted as a client and the other as a combined client and server, so two instances of the same application could be tested running simultaneously across the devices. The server contained a Microsoft SQL Server Database (Microsoft, 2012c) which contained a single table named Exercise. The Exercise table contained 2 attributes named id and video. The Exercise table had a single record containing properties for the id and video attributes. The laptops were connected via a wireless router. A WCF application was created that passed a simple set of messages from the WPF clients to the server. The first message created a connection between the server and the clients. The second message loaded up the video from the server to each of the clients simultaneously.

The WPF and WCF technologies provide a solution that supports a client-server architecture. The technologies can be run securely across a standalone network. The WPF technology allows audio and visual data to be presented in either 2D or 3D format. The libraries within the WPF technology provide the facility to work with other technologies such as Microsoft Word, which support the development of a facility to generate a report from exercise data as required by the HSE. The WPF and WCF technologies support the use of an SQL server database which can be used to store relational data such as exercises, resources and users. The solution can be run across devices running Windows operating systems such as laptops, tablets and Windows phones making it a lightweight and portable solution. WPF, WCF and SQL Server are the technologies that the prototype is built upon.

6.2. The Software Prototype

A software prototype was developed to facilitate the investigation of the application of software simulation to enable the testing and training of emergency response planning strategies. The components that make up the system architecture of the prototype are described. The process of setting up and performing an exercise using the prototype is presented.

The software prototype consists of three parts:

1. The application software
2. The server software
3. The database

The technology is designed so that it can be used on a simple network such as one created with a small wireless network hub. The model shown in figure 11 shows the configuration for the application, server, database model; where the application software represents the Presentation Layer and the server software represents the Business Logic. Once the application software is connected to the server software the system is ready for use. Multiple users may log on to an exercise at any one time. All three components are required to run the prototype system, each component is described in further detail.

6.2.1. The Application Software

The application software is designed using WPF technology and provides a GUI between the user and the system. The application software is a single executable file that should be installed on a device such as a PC or laptop that has access to the running server software and database via the network hub. The first screen a user is presented with is the log in screen. The account the user logs in with determines the information provided to the user. There are two types of accounts available: a user account and an administrator account.

6.2.1.1. The User Account

A user may not log into the system until the server has been activated by an Admin user. When a user logs into the system with a user account they will be shown a message upon logging in that gives them some information about the role they have logged in to. Figure 16 demonstrates an example of the information presented to a user when they are logged in to the system.

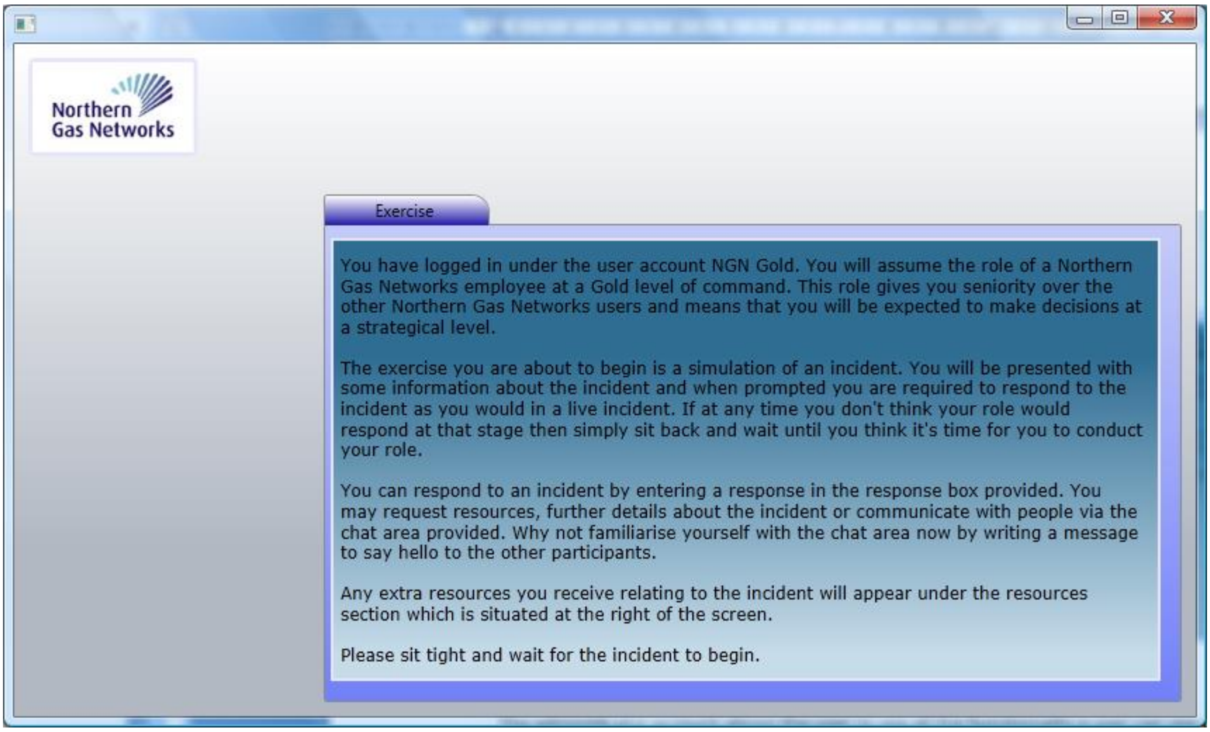

Figure 16 Log in screen

6.2.1.2. Administrator Account

The administrator account provides extra options to the user account. When logging in as admin the user is offered two options:

1. Run an Exercise

2. Database Administration

The first option allows the user to run an existing exercise. The second option is used to add or edit exercises, resources and users. The Admin must be logged in to the system to activate the server before other users may access the system.

The administrator account allows the user to see all the functionality a user can see with the addition of an administration panel (figure 17). The administration panel provides access to extra features such as being able to create and maintain user accounts and exercises and facilitating the running of exercises.

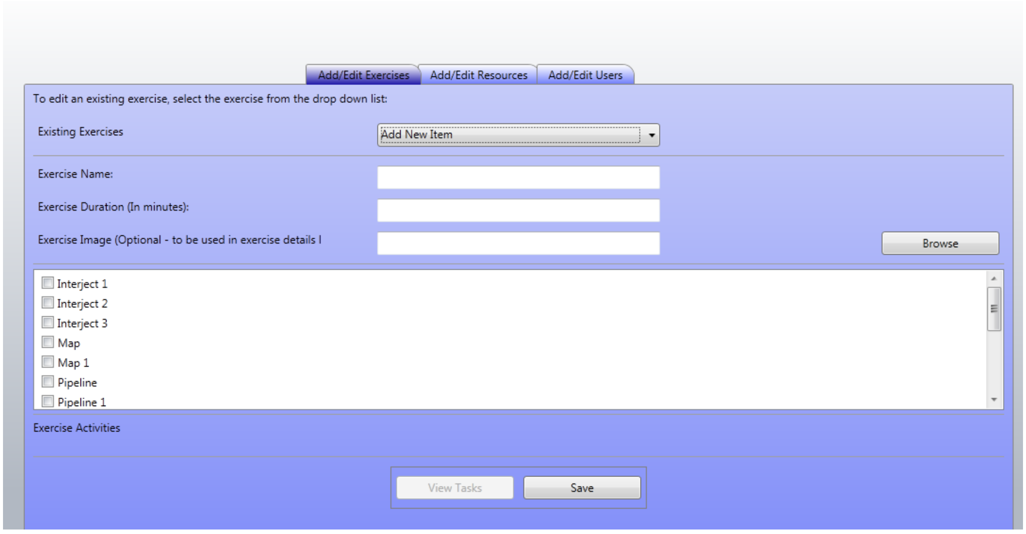

Figure 17 Administration Panel

6.2.1.3. Facilitating an Exercise

An exercise can only begin when the administrator activates it. The administrator is presented with a list of existing exercises within the system from which to choose. Once all the participants have logged into the system and are ready the administrator selects an exercise to run. Upon activation the system logs the details of all users into the system and all the exercise details are stored within an exercise instance log, the log serves to provide the data required to generate an exercise report. Each item recorded into the log is done so with a time and date stamp.

When an exercise is run the system displays the first scenario from the exercise in the main content area as defined within the database, this may be a video of an incident, an image or some text depending on how the exercise has been created. Figure 18 demonstrates a view of a video that has been created with a 3D replica of an existing site. The details of the scenario are recorded within the exercise instance log.

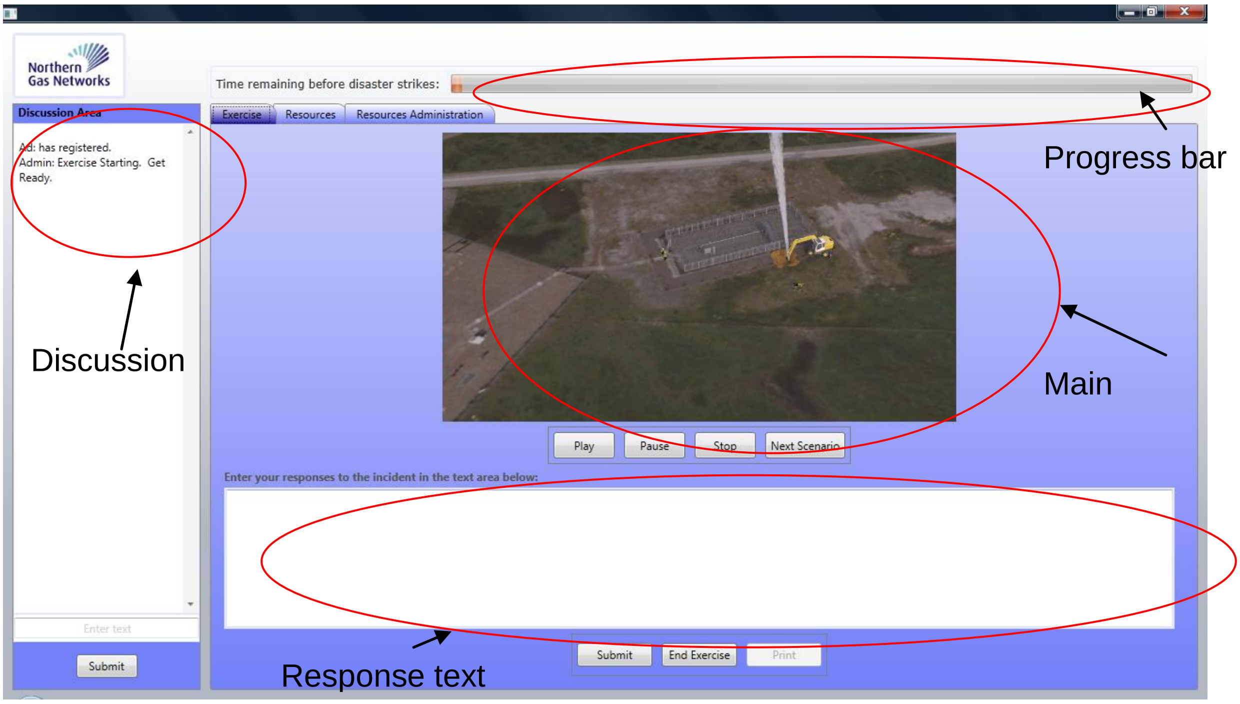

Figure 18 3D Video Scenario

The participants are presented with the first scenario and invited to respond with their actions in the text area at the bottom of the screen. Throughout the exercise a progress bar runs across the top of the screen to demonstrate how much time is left within the exercise. Once users have submitted their response to a scenario the system logs the response in the exercise instance log and displays the next scenario, again this could be a video, image or text depending on the design of the exercise. This process continues until the participants and the exercise facilitators agree that the incident is under control and therefore complete. Participants can communicate with other users online via the discussion area located to the left of the screen.

6.2.1.4. Exercise Resources

Users can request resources such as an emergency plan or weather information via the discussion board. Each time a message is submitted to the discussion area it is recorded within the exercise instance log. Only administrators have access to such resources and may release resources as required. When a resource is released the users receive notification of the release via the discussion area and the resource information is recorded within the exercise instance log. Resources can be viewed by clicking on the corresponding resource panel within the resources tab. Figure 19 shows an example of a map resource being viewed within the software.

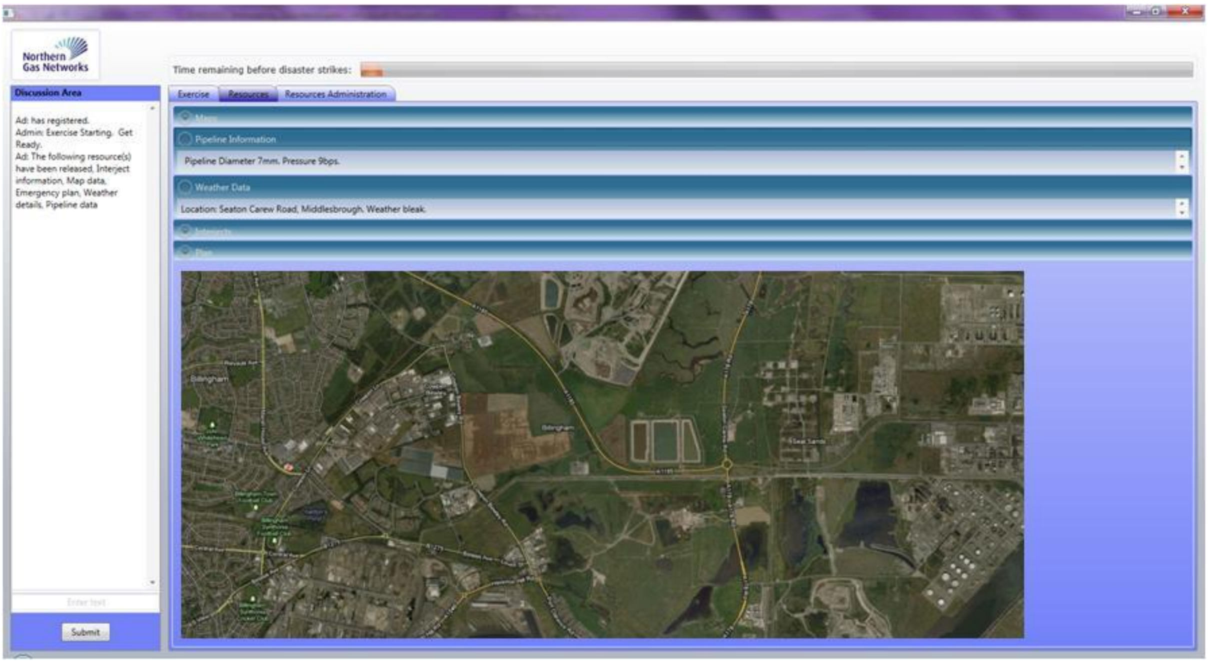

Figure 19 Map Resource

The different types of resources currently supported by the system include maps, pipeline information, weather information, interjects and plans.

Maps

Map information can either be supplied in the form of an image of a map or a direct link to a location on Google maps. Where a link to Google maps is provided the map is opened in the default web browser of the device the system is running on.

Pipeline Information

Textual information about a pipeline can be stored such as the size, pressure, location or any other data related to the pipeline.

Weather Data

As with pipelines, textual data about weather information can be added to an exercise. The data can be amended to reflect the current weather experienced on the day of an exercise.

Interjects

Interjects are also text based, although unlike the weather data and pipeline information they follow a specific format which includes information about who the interject is from, to and the details of the interject. Figure 20 demonstrates some examples of interject information.

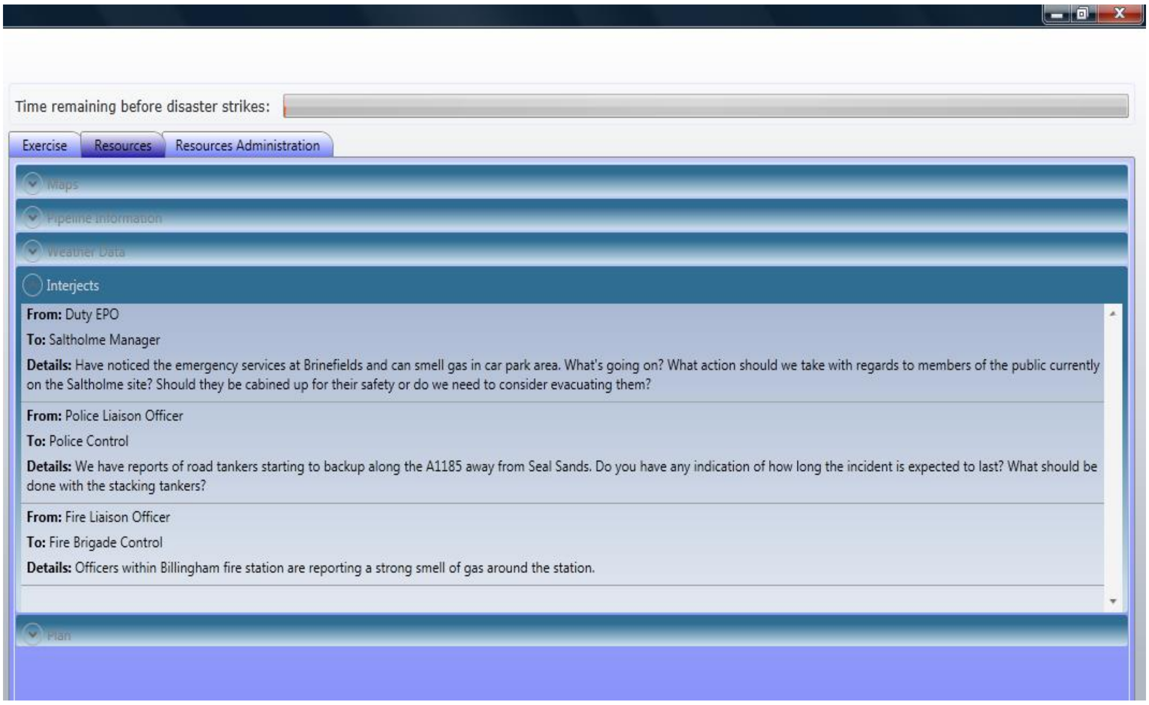

Figure 20 Interject Resource

Plans

Plans are stored as separate PDF files, links to both onsite and offsite emergency response plans of the organisation responsible for running the exercise can be added. When a user clicks on a link to a plan the PDF is opened as a PDF file. The device that the system is running on requires a PDF reader such as Adobe reader to be installed for the PDF to be viewed.

6.2.1.5. Administration Features

The administrator account provides access to a range of features that a user account does not. In addition to being able to activate an exercise, an administrator has the ability to hide and display resources, add exercises, add user accounts and generate reports.

Adding an Exercise

To add an exercise the administrator chooses to create a new exercise. The exercise is given a name and an associated image. When the system is started up with a view to running an exercise, all the exercises are listed along with their images as links which are used to initiate an exercise. Once an exercise has been created the administrator has the option to add tasks, resources and users. Existing exercises can also be edited.

Adding Tasks

The administrator has the option to add, edit or view existing tasks within the system. There are three different task types: textual description, image and video. Only one task type is associated with a task. If the administrator wanted to set up a task that ran a video then they could do so by selecting the video type and browsing to the video they wanted to display for that task. Similarly they can add a textual description or image for a task (figure 21).

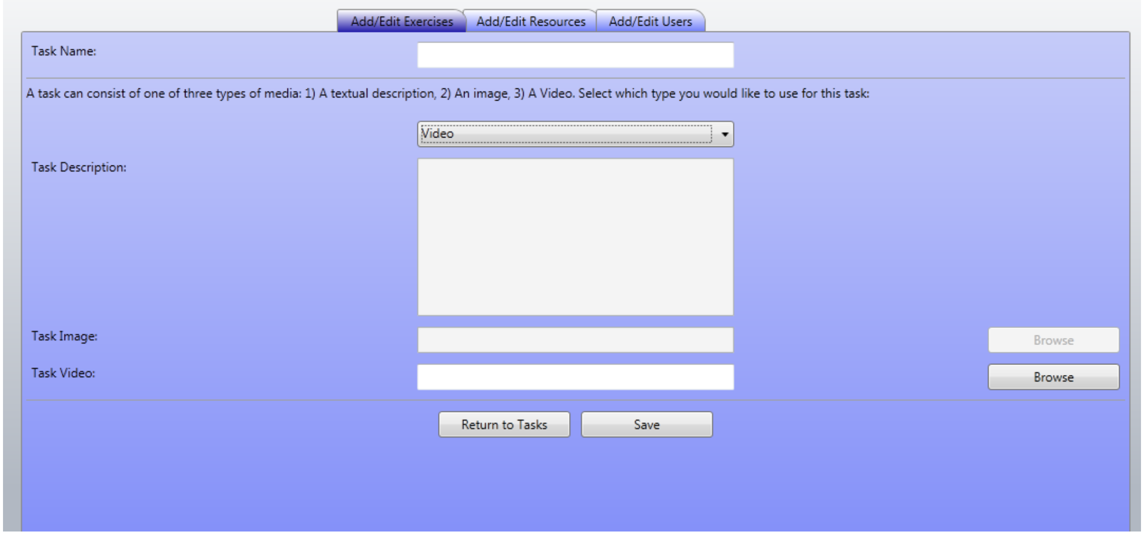

Figure 21 Add Task Form

Existing tasks may be added to an exercise. This removes the need for creating duplicate copies of the same task for different exercises and allows reuse of data.

Adding Exercise Resources

The system allows six different resource types to be added:

1. Interject
2. Maps
3. Pipeline Information
4. Plan
5. Scenario
6. Weather Data

When adding weather data, scenarios, interjects and pipeline information, the administrator is presented with a form in which they submit the relevant resource data. When adding maps and plans there is an option to browse to a copy of the map data or plan. As with tasks it is possible to reuse resources across multiple exercises without having to add them individually.

Adding a User Account

When adding a new user the administrator creates a new user account with a unique username and password. Each user is associated with an organisation such as Fire Rescue Service or Police. Each user has a role description associated with it, this is a textual description that defines the role of the user within the exercise. The role description provides the text that is displayed when a user logs in to the system.

Generating Reports

Once an exercise is complete the administrator has the option to generate an exercise report, the detail of which can be used as evidence to show the HSE that a plan has been tested. The report logs the following information from the exercise:

1. Name of exercise
2. Date of exercise
3. Start and end time of exercise
4. Username and organisation of each user that participated within the exercise
5. All tasks run within the exercise to include the following detail:
   a. Task name and time task was initiated
   b. Response details and username of the user that submitted the response
6. Name of resources issued along with the time they were issued
7. Discussion details:
   a. Discussion text
   b. Username of the person who submitted the discussion text
   c. Time that the discussion text was submitted

6.2.2. The Server software

The database and the server software must be installed on a single machine such as a laptop or PC that can be accessed on a network. The server software is generated using WCF technology and contains all the business functionality to allow messages to be passed between the GUI and the database across a network.

6.2.3. The Database

The database is an SQL database. The database contains all the data required for information regarding exercises, resources, tasks, users and discussions.

6.3. The Pilot Study

A pilot study was performed to both test the research approach and as a preliminary test of the prototype. The pilot study was hosted at the Virtual Reality Suite based in Northumbria University. The study was conducted by the primary researcher, a representative from NGN and a second researcher. The primary researcher's role was to facilitate the exercise, observe the other participants' actions, test the software and test the research process. The second researcher and the NGN representative's roles were to test the software, contribute to testing the research process and to provide some preliminary data regarding the experience of using the software simulation to test an emergency response plan.

Each participant played the role of a person from an agency likely to be involved in the final experiment. The NGN representative played the role of a gas engineer. One of the researchers played the role of a Police representative and the other the role of a FRS representative. Each agency was assigned a coloured pen and corresponding Post-it notes. The colour coding was used to identify responses against roles. The NGN representative was assigned the colour black, he was given a black pen and white Post-it notes to complete the activities with. The FRS representative was given a red pen and pink Post-it notes and the Police representative was given a blue pen and blue Post-it notes. Wherever a response was required to be written or a Post-it note supplied each participant would submit it in their assigned colour.

The experiment was split into four phases each capturing different types of information:

1. Phase One: Participant experience in emergency planning.
2. Phase Two: Participant computer experience.
3. Phase Three: Participant expectations of the simulation. Simulation demonstration. Participant experience of the simulation.
4. Phase four: Questionnaire to capture demographic data, information regarding communicating with other agencies, experience with technology, emergency response planning and their simulation experience.

6.3.1. Phase One: Participant Experience in Emergency Planning

Phase one contained two activities: a brain storming session to capture the participant perception of tabletop role play for testing emergency response strategies and a timeline exercise aimed to capture information about the events that took place at an incident.

6.3.2. Brainstorming Opinions of Tabletop Role Play

During the first brainstorming session participants were presented with an A3 piece of paper, which contained the text "*What do you think the current tabletop role playing method for testing emergency response plans does well?*". Participants wrote their responses onto their piece of paper with the coloured pen assigned to them. During the brainstorming session, participants were asked by the researcher to elaborate on points, so more detailed information about responses could be captured.

Once the first stage had been completed, a second piece of A3 paper was handed out to the participants containing the text "*What do you think the current tabletop role playing method for testing emergency response plans doesn't do well?*". Again participants were asked to write their responses on their sheet of paper and to elaborate on points made.

6.3.3. A Timeline of Emergency Response Events

The third stage of this section was to capture a timeline of events that took place during an emergency response activity. Participants were supplied with an exercise designed to test an emergency response plan. The exercise provided a scenario of an incident involving a major gas pipeline. Participants were asked how they would respond to such an incident and provide a timeline of the likely events that would happen. The timeline was provided in the form of an A3 piece of paper with a line through the middle. At the beginning of the line was the text "*start of incident*" and at the end was the text "*end of incident*". The different responses from different agencies were written along the timeline in their respective assigned coloured pen. Upon completion of the timeline exercise, participants were asked again what they thought about the current tabletop method for testing emergency response plans and their responses were recorded by the researcher.

6.3.4. Phase Two: Participant Computer Experience

During this stage the researcher asked the participants to shout out a list of software they had used. The researcher wrote these down on a piece of flip chart paper and gave each item a number. The participants were then asked to write on their assigned coloured Post-it notes, details of good and bad experiences they'd had of using any of the software listed. The participants were also asked to write the number of the item from the list on their Post-it so their responses could easily be identified.

6.3.5. Phase Three: Expectations and Experiences of the Software Simulation

Phase 3 contained three activities. The first activity was a brainstorming session which served to capture the participants' perceptions on virtual simulation for applying emergency response planning strategies. The second activity was a demonstration of the virtual simulation prototype. The third activity was a further brainstorming session on participant perception of the virtual simulation for applying emergency response planning activities after the prototype had been demonstrated.

6.3.6. Brainstorming Expectations

Participants were given A3 sheets of paper containing the text "*What do you expect of a computer simulation for running an emergency planning exercise*?". Participants were asked to write comments on the paper regarding the question with their assigned coloured pen. The researcher asked participants to elaborate on their responses to capture more detailed information.

6.3.7. Running the Software Simulation

The software prototype simulation was run on a single laptop and projected onto a screen. The simulated exercise was initiated by the researcher who acted as the facilitator. The simulation began with the researcher selecting an exercise to run. The content from Exercise Dragon was used to conduct the simulation exercise with the prototype. When an exercise was initiated the participants were presented with a 2D representation of a 3D video animation of an incident. The video presented an audio and visual representation of the incident.

Once the video had ended the participants were asked for their initial response to the incident. The responses were entered into a text area within the simulation and recorded within the database. Each response was displayed in the discussion area. The discussion area is an element within the simulation that allows users to send and receive messages, in addition to requesting resources and communicating with other users. Once the first response was received, a second 2D representation of a 3D video animation was played. This video showed an aerial view of the area where the incident was set. It was explained that the final cut of this video would have a voice over of the phone call a first call operative would receive about an incident. For the purpose of the exercise the information from the call was delivered verbally by the exercise facilitator.

The NGN representative was asked to respond to the exercise in the same way as he would at a tabletop role play exercise. His responses were entered into the software and various elements were shown to demonstrate how requests could be made for resources and how the resources could be released. When the exercise was completed, it was run again using 3D stereoscopic animated videos of the scenario simulation, stereoscopic 3D glasses were used to view the scenario.

The simulation was a WOZ prototype, elements such as a progress bar to simulate a timeline for tasks to increase the urgency to respond to a task were not included within the prototype. Other items not available during this iteration of the prototype included geographical map data, pipeline data, weather data and interjects. These resources were included within the final comparative evaluation study.

6.3.8. Brainstorming the Software Simulation Experience

When the software simulated exercise was complete another brainstorming session was held to capture participants' opinions about the simulation. Each participant was given a piece of A3 paper containing the text "*What are your opinions of the computer simulation for running an emergency response planning exercise?*". Participants provided their responses by writing on the paper in their assigned coloured pens and were asked by the researcher to elaborate on their answers. Further detailed responses were captured on a voice recorder.

6.3.9. Phase Four: Questionnaire

A final questionnaire was handed out to participants. The questionnaire served to capture information such as: demographic data; emergency response planning experience; technology experience; communicating with other agencies; and software simulation as a medium for testing emergency response plans.

6.3.10. Findings from the Pilot Study

The pilot study served to highlight any changes required to the virtual simulation prototype before it was accepted as being ready for the main comparative evaluation study. The pilot study also served to test the research methods and process. The amendments to both the prototype design and the research approach that arose in response to the pilot study are documented in this section.

6.3.11. Amendments to the Prototype Design

In response to the prototype testing, the COMAH organisation representative requested an initial screen be shown when a user logged in. The screen was required to contain information regarding a user's role, outlining what was expected of them during the exercise. This was included in the prototype for the main comparative evaluation study.

6.3.12. Amendments to the Research Approach

The first task which served to capture information about tabletop role play revealed that it was difficult to isolate responses of good and bad points about the current process for testing emergency response plans. In response to this it was decided that rather than ask the questions regarding what the method does and doesn't do well, the words "*Tabletop role playing method*" would be written on the paper and the participants asked to present their thoughts on that statement. This approach was taken to allow for a more open ended method of asking the question without leading participants into giving subjective answers based on the researcher's opinion.

The timeline exercise revealed that different agencies would have a different view of what was considered the start and end of an incident. Depending on the role being assumed in an incident, these terms held different meanings for different agencies. The NGN representative thought that the information gathered during the timeline exercise would contribute to improving NGN's internal understanding of the emergency response process, thus helping improve internal emergency response procedures. The information from the timeline exercise will be assessed to see if there are any discrepancies in the software simulated prototype that may impact on the perception the participants have towards the perceived usefulness or perceived ease of use of the software to conduct an exercise.

One of the questions included in the questionnaire aimed at capturing information regarding computer experience posed the question:

How often do you use technology to conduct activities outside of work?

The following likert scale was provided to capture the response.

○	○	○	○	○	○
I don't use it	I use it for 25% of activities or less	I use it for around 25-50% of activities	I use it for around 50% of my activities	I use it for around 50-75% of my activities	I use it for 75-100% of my activities

The same question was asked of computer experience within work with the same likert scale response. The NGN representative found it difficult to quantify his none working time in percentages. After further discussion it was agreed by all participants that due to there being a set amount of time allocated to work in a week, the tasks conducted as part of the working day could easily be quantified in terms of percentages. However, it was felt that it wasn't as easy to quantify the time spent on activities outside of work in percentages, as the time was spread out over many activities such as eating and sleeping. To quantify the time in hours seemed more applicable than using percentages, when dealing with allocating time spans to activities outside of work. The questionnaire was changed to reflect this finding:

How many hours do you think you use technology to conduct activities outside of work in a day?

○	○	○	○	○	○
I don't use it	I use it for up to 1 hour per day	I use it for around 1-3 hours per day	I use it for around 4-6 hours per day	I use it for around 7-10 hours per day	I use it for more than 10 hours a day

This chapter has described the process used to develop a prototype to evaluate user perceptions of software simulation to test emergency response plans. A pilot study has been performed to test both the research approach and the prototype. The prototype and methods have been amended in response to the findings from the pilot study. The process of performing the main study is described in the next chapter.

Chapter 7 The Software Simulation Prototype Evaluation Approach

The main evaluation of the software prototype to perform the emergency response planning exercise was conducted in the Virtual Reality Suite based in Northumbria University. The background and role of the research participants' are documented. As with the pilot study the experiment was split into four parts, the detail of which are described in this chapter.

7.1. The Research Sample

The study included 8 participants from a range of agencies representative of those that attend tabletop role play exercises to test emergency response plans for high pressure gas pipelines. All participants were familiar with the concept of using tabletop role play for exercises to test plans to satisfy COMAH regulations. Each participant's role was COMAH related, either in the context of developing emergency response plans or in ensuring plans were tested to meet COMAH regulation. Table 16 describes the job titles, roles and level of command each participant has with their agency.

Table 16 Research Sample

Participant	Agency	Job Title	Role	Level of Command
1	FRS	Emergency Planning / COMAH Officer	To advise in emergency response planning both for developing exercises and at an incident.	Silver
2	NGN	Graduate Engineer	Responsible for ensuring company meets COMAH regulations.	Bronze
3	NGN	Network Integrity Officer	Responsible for ensuring company meets COMAH regulations.	Bronze
4	NGN	HSE Support Manager/Operational Manager	Health and Safety and Operational advisor.	Bronze
5	Police	Emergency Planner	Advise tactical commanders on how to proceed in an incident.	Silver
6	Police	Emergency Planner	To advise at a tactical and strategical level for both planning exercises and at an incident.	Gold/Silver
7	LA	Emergency Planner	Responsible for ensuring the Local Authority meets COMAH regulations. Developing offsite plans and exercises to test the plans for COMAH sites.	Silver
8	LA	Emergency Planner	Developing plans for COMAH sites.	Bronze

The experience the participants have of emergency planning exercises and technology usage is documented in table 17. All participants have either participated in or been part of the development process of an exercise to test emergency response plans. The amount of time participants spent using software technology both for work and non-work related activities, was captured to facilitate an understanding of the level of experience participants had with using technology. A detailed investigation into the types of technology the participants were familiar with using is described in Chapter 8 Section 8.1. All participants used some form of software technology for at least 50% of their work activities, with the majority of the group using technology for more than 50% of work activities. All participants also used software technology for non-work related activities on a daily basis.

Table 17 Participant Profiles

Participant	Age	Number of Exercises Participated in	Number of Exercises Participated in the last two years	Number of times involved in developing an exercise	Percentage of work time using software technology	Number of hours spent using software for activities outside of work	Amount of time spent communicating with other agencies using software
1	50	>3	>3	>3	50-75%	1-3 hours	Daily
2	23	1	1	0	75-100%	Up to 1 hour	Weekly
3	26	0	0	1	75-100%	Up to 1 hour	Daily
4	49	2	2	1	50-75%	1-3 hours	Once a month<
5	46	>3	>3	>3	50-75%	1-3 hours	Daily
6	51	>3	>3	>3	75-100%	1-3 hours	Daily
7	53	>3	>3	>3	50%	Up to 1 hour	Weekly
8	28	>3	>3	>3	50-75%	1-3 hours	Daily

The researcher facilitated the tasks throughout the study with assistance from a second researcher. The second researcher's role was solely to assist in the facilitation of the tasks. The research sample included a range of participants from the Police, FRS, LA and NGN, the details of their roles, the agency they represented and the level of command they represent within that role are shown in table 18.

Table 18 Research Sample

Role	**Agency**	**Level of Command**
Emergency Planning / COMAH Officer	FRS	Bronze
Graduate Engineer	NGN	Bronze
Network Integrity Officer	NGN	Bronze
HSE Support Manager/Operational Manager	NGN	Silver
Emergency Planner	Pol	Silver
Emergency Planner	Pol	Silver
Emergency Planner	LA	Silver
Emergency Planner	LA	Bronze

All participants except the NGN Network Integrity Officer had attended and participated in Exercise Dragon (see 6.1.3 for details of the exercise). None of the participants except the NGN Graduate Engineer had any previous experience with the newly developed virtual simulation prototype. Each participant was asked to complete a consent form before commencing the study. The purpose of the study was described and the way in which the data was to be used was explained to the participants. Each participant was given a unique coloured pen and Post-it note with which to submit their responses to the exercises, so the responses could be cross-referenced with the agency details during the analysis stage. The purpose of the coloured coded equipment and how participants should use them to engage in activities throughout the study was explained by the researcher. An audio recording of the study was captured and transcribed, so detail discussions held during the tasks could be captured.

7.2. Phase One: Participant Experience in Emergency Planning

7.2.1. Brainstorming Opinions of Tabletop Role Play

The first task involved a brainstorming session regarding the current tabletop role playing method. Two pieces of flip chart paper containing the text "*Tabletop role playing method*" were presented to the group and each participant was asked to write down their thoughts regarding this statement. The purpose of using two pieces of paper to capture this information was due to the size of the group. Many of the participants found they wanted to write the same thing that had been written by another participant. To avoid duplication of effort it was agreed by the researcher and the group that if a participant agreed with a statement they could mark a tick next to the statement to show they agreed and if they had anything to add to the statement they should write down a separate comment. All participants reviewed the comments on both pieces of paper and contributed their written comments where required. The responses prompted discussions between the participants that revealed further detail about the responses. The researcher asked for further comments where the responses were not clear. Appendix 9 contains the data captured from the brain storming activity in Phase One.

7.2.2. Timeline of Emergency Response Events

The second stage of phase one aimed to capture a timeline of events that took place during an emergency response activity. Participants were supplied with a scenario form Exercise Cornerstone (see Chapter 6 Section 6.1.2 for details). Participants were asked how they would respond to such an incident and provide a timeline of the likely events that would happen. A single piece of flip chart paper was provided, at one end of the paper was the text "*start of incident*" with "*end of incident*" at the other end. The participants were asked to write on the timeline the different stages that would occur during the incident. The end of the incident was signalled as when the incident was declared as under control. The term under control has different meanings for different agencies so to clarify further it was agreed that 'under control' meant that the incident was no longer a 'major incident' (as defined in Chapter 2 Section 2.1).

7.3. Phase Two: Participant Computer Experience

This task involved the researcher asking the participants to write down the details of their experience of using computers. The researcher explained that in addition to work related applications, non-work related activities such as using mobile phone, music, photograph or internet applications were all valid responses to the task. As with the first task, where participants had a response that was the same as another response, they marked the response with a tick to show they had used that software. Each response was numbered by the researcher. The participants were then asked to write on their assigned coloured Post-it notes, details of good and bad experiences they'd had of using any of the software listed. The participants were also asked to write the number of the item on their Post-it that related to their responses so that the response could be linked to the software. Participants were asked to provide details of whether their experiences had been positive or negative and were encouraged to give reasons to support their opinions.

7.4. Phase Three: Expectations and Experiences of the Software Simulation

7.4.1. Brainstorming Expectations

For this task three participants were given a piece of flip chart paper with the text "*What do you expect of a computer simulation for running an emergency planning exercise*?". The participants were asked to write comments on the paper regarding the question with their assigned coloured pen. The researcher asked participants to elaborate on their responses to capture more detailed information. The verbal responses to these questions were recorded with a voice recorder and transcribed. The range of comments made are located in Appendix 13.

7.4.2. Running the Software Simulation

Stage two of phase three involved running the simulation which was projected onto a screen whilst being run simultaneously on three laptops that were connected via a wireless router. The participants were arranged in groups around the laptops. The simulation software was initiated by the researcher who acted as the facilitator. Each group was given the log in details for a user account on the system. When each group logged into the system, they were presented with a screen that provided a description of the role they had logged in as and what they should expect from an exercise. The exercise began when the researcher selected an exercise. As with the pilot study, Exercise Dragon along with its associated resources was used as the exercise with which to conduct the simulation. The participants were presented with a 2D representation of a 3D video animation of an incident. The video presented an audio and visual representation of the incident.

When the video ended the participants were asked for their initial response to the incident. The responses were entered into the response text area within the simulation and recorded within the database. Each response was displayed in the discussion area. The researcher explained that in addition to showing the responses in the discussion area, the area could also be used to send messages to other participants and to request resources. The participants submitted some messages to each other via the discussion area and requested some resources. The researcher supplied the resources as and when requested. The resources included map data, pipeline data, weather data, the plan and interject information.

When the exercise was completed, a second version of the exercise was initiated using 3D stereoscopic animated videos of the scenario simulation, stereoscopic 3D glasses were used to view the scenario. During both versions of the simulation the participants asked questions and held discussions regarding the simulations, the detail of which was recorded on a voice recorder and transcribed.

7.4.3. Brainstorming the Virtual Software Simulation Experience

When the simulated exercise was complete the brainstorming session to capture participants' opinions about the simulation was performed. The participants were provided with two pieces of flip chart paper containing the text "*What are your* *opinions of the computer simulation for running an emergency response planning exercise?*". Participants provided their responses by writing on the paper in their assigned coloured pens and were asked by the researcher to elaborate on their answers. The participants reviewed the comments on both pieces of paper and further discussion was held regarding the comments between the participants. Details of the opinions held by the research sample regarding the use of the software simulation for exercises to test emergency response plans were captured. Participants were asked to provide details of both positive and negative opinions and were encouraged to give reasons to support their opinions. The opinions were discussed in the context of the tabletop role play method along with what the system could bring to an exercise (Appendix 11; Appendix 12).

7.5. Phase Four: Questionnaire

For the final part of the simulation the participants were asked to complete the final questionnaire. A copy of the questionnaire that was used in the study can be found in Appendix 16. Appendix 17 provides the data that was captured within the Questionnaire.

The process of the study to capture research participant perceptions and opinions of a virtual simulation for testing emergency response plans has been described. The research sample has been introduced and the methods for capturing the data documented. In the next chapter the data is analysed and the key findings identified.

Chapter 8 A Comparative Evaluation of Tabletop Role Play and Software Simulation methods for Testing Emergency Response Plans

An analysis of the user evaluation of both the system currently used and of the software simulated prototype as applied to emergency response planning strategies reveals a number of themes relating to Perceived Usefulness (PU) and Perceived Ease of Use (PEU). Themes such as learning through feedback and consequence, the ability to represent communication and movement and the potential to use the system as a decision making audit trail are just some of the themes presented within this chapter. Furthermore, the TAM is applied to the analysis of opinions relating to software used by the research participants in general, in an attempt to offer an explanation for the potential adoption and use of the software simulation prototype. This analysis chapter presents emergent themes and discussions concerning the PU and PEU for both tabletop role play and software simulation. The key findings are examined and the extent to which the TAM explains intention to use the software is discussed.

8.1. Applying the TAM to Understand the Research Participant's Acceptance of Systems Currently Used

Understanding the relevance PU and PEU play on the software currently used by the research participants may provide some understanding on their intention to use software. PU showed more relevance that PEU in an evaluation which applied these TAM constructs, to the opinions of software currently used by the participants. The participants highlighted 61 different software applications that they'd had experience in using (Appendix 9: Table 34). Each participant provided comments regarding their experiences with each of the applications listed, 119 comments were provided in total (Appendix 9: Table 35). The role PU and PEU have on the acceptance and use of the software systems currently used by participants is considered in an attempt to highlight any significant factors that may impact on their Attitude Towards (AT) using and Behavioural Intention (BI) to use the software simulation prototype for emergency response planning strategies.

The applications most commonly used by the participants are: Microsoft Outlook; Microsoft Excel; Microsoft Word; Microsoft PowerPoint and Google Street View (Appendix 10: Figure 29). All the participants stated that Microsoft Word was easy to use. There was a common agreement that Microsoft Outlook was also easy to use. The majority of participants liked using Microsoft Excel, one participant stated that they "Use it [Microsoft Excel] every day" because it was "Easy to use", they also stated that they "Love it [Microsoft Excel]" and that it produces "great quick results". Whilst the majority agreed that they thought Microsoft Excel was a good program, PEU was demonstrated as something Microsoft Excel was lacking. One participant stated that Microsoft Excel "Takes a while to get most out of it". Another described how Microsoft Excel was "Not to user friendly for those not good with computers". Whilst the initial ease of use was not apparent in Microsoft Excel, the common agreement was that with training it became easy to use and useful.

Although the research participants perceive Microsoft Excel difficult to use, they also believe it is useful and therefore requires the correct training in order to receive the benefits it provides. This finding correlates with the TAM theory that AT and BI are a result of PU and that whilst a user may not like a system they may still use it if they perceive it to enhance their job performance (Taylor and Todd, 1995). The participants' attitude towards using Microsoft Excel supports the theory that if users from the research sample believe a software application will enhance their job performance they would be willing to learn how to use it. The TAM constructs that apply to the AT and BI of Microsoft Word and Microsoft Excel are shown in table 19.

Table 19 Opinions Relating to Software Use

Method	**Construct**	**Reason**
Microsoft Word	PEU	Easy to use
Microsoft Excel	PU	Difficult to use initially but useful once trained in use

Microsoft Outlook was identified as the most appropriate software for communicating with other agencies, text messaging was the second most common (Appendix 17). Reasons relating to the PU of Microsoft Outlook were provided as an explanation as to why it was perceived to be the most appropriate for communicating with other agencies (Appendix 17). Participant 1 stated that Microsoft Outlook provides a "quick and easy" [method to communicate]. The ability to provide a log or audit trail of communication was a second benefit associated with Microsoft Outlook highlighted by Participants 1, 2 and 8 (Appendix 17). In relation to Microsoft Outlook Participant 1 described how it "assists in with keeping a record of contact and what was discussed", Participant 2 stated that it "documents everything" and Participant 8 discussed how it "can be used as a log for communications" (Appendix 17). The ability to send a single message to multiple participants was another benefit highlighted by Participant 8 that Microsoft Outlook offered along with the ability to send secure messages such as sensitive plans and other documents (Appendix 17). Table 20 expands table 19 to show the items highlighted from the participants that impact on use of Microsoft Outlook.

Table 20 Opinions Relating to Software Use

Method	Construct	Reason
Microsoft Outlook	PEU	Easy to use
Microsoft Word	PEU	Easy to use
Microsoft Excel	PU	Difficult to use initially but useful once trained in use
Microsoft Outlook	PU	Quick and easy method to communicate.
Microsoft Outlook	PU	Audit trail of correspondence.
Microsoft Outlook	PU	Send a single message to multiple recipients.
Microsoft Outlook	PU	Send sensitive plans via a secure email

It was generally agreed that Microsoft PowerPoint was easy to use. The opinions concerning the use of Google Street View were positive with varying reasoning for use. Half of the participants found it useful whilst the other half found it easy to use. Two of the participants attributed Google Street View as being useful in contributing to the facilitation of their work activities. Table 20 has been expanded to show the range of constructs attributed to the acceptance and use of the systems most commonly used by the research sample in table 21.

Table 21 Opinions Relating to Software Use

Method	Construct	Reason
Microsoft Outlook	PEU	Easy to use
Microsoft Word	PEU	Easy to use
Microsoft Excel	PU	Difficult to use initially but useful once trained in use
Microsoft Outlook	PU	Quick and easy method to communicate.
Microsoft Outlook	PU	Audit trail of correspondence.
Microsoft Outlook	PU	Send a single message to multiple recipients.
Microsoft Outlook	PU	Send sensitive plans via a secure email
Microsoft PowerPoint	PEU	Easy to use
Google Street View	PEU	Easy to use
Google Street View	PU	Useful for assessing street make up

Out of the 119 comments made with regards to software applications the case study group had experience of using, 94 comments described a positive experience with using the software. Out of the 94 positive comments, 16 comments were in relation to PU and 47 were related to PEU (Appendix 9: Table 35). The remaining 31 positive comments did not relate to PU or PEU, there was no commonality between them, containing statements such as “recorded images from site”. Out of the 119 comments made, 25 related to a negative experience of using software. Out of the 25 comments made relating to negative experiences with using software, 20 of the 25 were related to PEU, 4 were related to PU and 1 was related to the system becoming obsolete (Appendix 9: Table 35). The range of comments relating to both the positive and negative experiences of existing systems used by participants and the impact PEU and PU has in relation to these experiences is shown in figure 22.

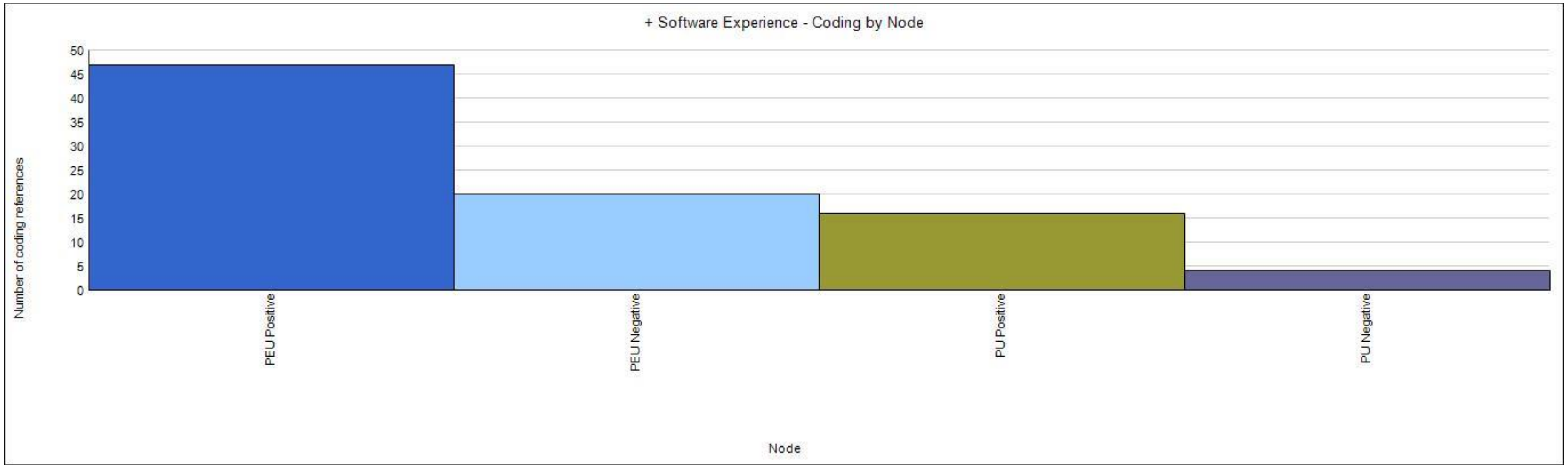

Figure 22 Software Experience Coding Analysis

Figure 22 indicates that PEU is more significant than PU in AT and BI for the software systems currently or previously used by the case study group. The most commonly used systems however, as shown in table 21, show 4 items relating to PEU and 6 items relating to PU, which demonstrates a small preference in the role of PU over PEU. Several existing studies demonstrate that PU is more significant than PEU in determining whether or not to use technology (Chau and Hu, 2001; Venkatesh, 2000; Chau, 1996; Keil et al. 1995).

The analysis so far has shown conflicting findings regarding the significance of PEU and PU and their impact on AT and BI. With regards to acceptance and use of software most commonly used by the research sample, both PEU and PU rate high in the acceptance and use of software. The TAM constructs PU and PEU have been applied to the research participants' understanding of their existing software experience and their relation discussed. At this stage of the investigation the researcher assumes that both constructs play a significant role in the acceptance and use of software by the research sample, however PU shows more relevance than PEU for the acceptance and use of systems currently most in use. PEU and PU are investigated further with respect to the potential use of a software simulation tool as applied to emergency response planning exercises.

8.2. Applying the TAM to Understand the Potential for Using the Software Simulation Tool for Emergency Response Exercises

One of the key issues highlighted by the research participants regarding the current tabletop role playing method was the lack of realism it imposed. A number of themes associated with attributing to lack of realism have emerged, these include:

a) Unrealistic response preparation time

b) Learning through feedback and consequences to actions

c) Enhancing the user experience using visual and auditory cues

d) The advantages of remote participation

e) Removing observers to reduce distraction

f) The benefits of online collaboration

g) The benefits of unrealistic timeframes

A number of benefits associated with the perceived usefulness of the newly developed software simulation prototype also emerged during the study, these include:

a) Testing emergency response processes

b) Decision making support tool for incidents

c) Cost effectiveness of tabletop role play and the proposed software simulation method

d) The portability of the software simulation tool for enabling emergency response planning exercises

The themes that emerged during the study are discussed in more detail within this chapter. The attitudes the research participants have towards using the software simulation for applying emergency response planning strategies are described. The emergent themes regarding realism and usefulness are now presented in turn.

8.2.1. Unrealistic Response Preparation Time

The perceived pressure to make decisions is thought to be greatly reduced during tabletop role play. Participant 4 stated “you’re not under pressure, you’re not under pressure to make a decision”. Unlike live incidents, tabletop role play provides an opportunity for exercise participants to prepare their response in advance. There was a common agreement amongst the research participants that responders regularly stated what they thought they should do, rather than what they would actually do in response to events at an incident (Appendix 12: Table 37). One participant described an incident involving a gas explosion from a terrorist attack that resulted in a large hole in a gas pipe. The participant explained how he felt that nothing could have prepared him for how he felt when he turned up at the incident and had to make an immediate decision.

Another participant used the analogy of walking round the corner and being faced with a fire as an explanation of how tabletop role play did not put you under the same sort of pressure as a live incident. The general agreement was that in a real situation responders didn’t know how they would react, but tabletop role play afforded the time to plan for an incident with an exercise (Appendix 12: Table 37). Having the opportunity to prepare for an incident was one feature that participants felt was unrealistic about tabletop role play. The research participants thought that too much planning and preparation time was given to responders during an exercise.

The software simulation prototype method for conducting emergency response planning exercises revealed a number of features that could contribute to increasing pressure and providing a more realistic environment. The software simulation has a progress bar which can be used to demonstrate the time remaining for either a task or an exercise. Allowing exercise participants to see the time counting down within the software was thought to put increased pressure on the responders to make decisions. Having a feature that demonstrates a time constraint for a response was something the participants thought would increase pressure on responders to make a decision. The provision of feedback and consequences and the use of detailed auditory and visual cues were also believed to contribute to increasing the pressure responders had on making a decision. These features are discussed further in the next two sections.

8.2.2. Learning Through Feedback and Consequences to Actions

The research participants agreed that tabletop exercises were not a good test of competency. Developing staff competencies and providing staff with an opportunity to practice carrying out their role in a plan is one of the key purposes the Cabinet Office (2010) proposes an exercise should serve. Responders are required to make decisions at exercises however, no facilities are provided within the current tabletop role play method to demonstrate the consequences of those decisions made. Six of the participants agreed with the statement “Doesn't [tabletop role play] test plans or processes and procedures named in the plan” (Appendix 12: Table 37).

One individual stated of the software simulation being evaluated that “you can check actual decisions against expected actions”, another highlighted the interactiveness of having feedback and consequences to actions as being a benefit of the system (Appendix 15: Figure 30). Participant 4 recommended using an example of demonstrating the consequences of what would happen if a gas valve was shut off, as opposed to gently reducing the load to that pipe and shedding the gas load elsewhere. Lee et al. (2005) indicate that studies applying the TAM have shown that the provision of immediate feedback enhances the learning experience in internet based learning. Previous research has demonstrated that simulators that provide feedback and consequences to actions, leave users feeling more prepared and having increased confidence for entering live experiences (Bremner et al., 2006; Henneman and Cunningham, 2005; Ausburn and Ausburn, 2004).

The software simulation provides exercise facilitators with the ability to provide real-time feedback and consequences to decisions made by users. The exercises can be developed with a bank of textual; graphical and auditory responses to be issued in response to decisions. The participants agreed that being able to provide feedback and consequences during an exercise would be useful in developing staff competencies in making decisions and applying the plan being tested. It was agreed that giving responders an opportunity to practice decision making activities through the software simulation would enable individuals to perform the decisions in a live situation. Research has shown that being able to repeatedly test out scenarios with different strategies prepares responders with a better understanding of what to expect at an incident (Campbell et al., 2008; Jain and Mclean, 2003; Simpson, 2001).

All the participants considered the software simulation to be good for training individuals how to implement a plan in an emergency situation, one participant stated that it would be “excellent” from an operational point of view for educating people in the consequences of their actions. Another thought that the ability to both receive and record decisions actions and responses enhanced realism. The ability to study actual responses against expected responses was something that was thought to be a useful feature of the system that could improve training (Appendix 15: Figure 30).

All participants agreed that software simulation of an exercise using the software prototype would be a good method for preparing responders in implementing a plan at an incident (Appendix 17). It was also agreed that the software prototype would provide an opportunity to test the responders’ understanding of the plan and experience feeling the pressures exerted from various areas, during the management of an incident (Appendix 15: Figure 30). The software prototype provided a mechanism that allows responders to go through the actions or processes of a plan and demonstrate any issues within the execution of the plan in a safe environment. Table 22 shows PU is an item associated with the software prototype to support the development of staff competencies through the provision of feedback and consequences. Table 22 expands table 21 to show the AT the software being used to train responders for implementing a plan.

Table 22 Opinions Relating to Software Simulation for Conducting Emergency Response Exercises

Construct	Reason
PU	The ability to get immediate feedback enhances the learning experience.
AT	It would be much better to use the software simulation tool to run exercises for preparing responders in implementing a plan in an incident rather than the current method.

The use of a bank of scenarios within the software simulation contributed to the PU of the software simulation, this theory is supported by the literature. Campbell et al. (2008) argue that whilst paper-based workshops may be good for testing a plan, software simulations provide an opportunity to repeatedly test out scenarios with different strategies more easily. Testing a scenario with alternative strategies prepares emergency responders with a better understanding of what to expect at an incident (Jain and Mclean, 2003; Simpson, 2001). Being able to show the same incident at different times of day to test different parameters such as light, traffic movement or wind speed, was another feature the simulation had that contributed to the PU of the system. It was found that the ability to reuse interjects and elements of a scenario, meant that the system allowed you to create more flexible exercises that could be reused thus reducing the amount of time and cost taken to develop a new exercise.

The research participants all agreed that the software simulation tool would be a good method to enable an exercise to test an emergency response plan (Appendix 17). The ability to have real-time feedback and consequences within the software simulation was thought to provide a more realistic environment, for testing both the plan and the processes involved in emergency response (Appendix 15: Figure 30). The ability to have a bank of scenarios to test out different strategies as an item of PU and the participant's AT the software simulation's ability to be used to test a plan have added to table 22 and are shown in table 23.

Table 23 Opinions Relating to Software Simulation for Conducting Emergency Response Exercises

Construct	**Reason**
PU	The ability to get immediate feedback enhances the learning experience.
AT	It would be much better to use the software simulation tool to run exercises for preparing responders in implementing a plan in an incident rather than the current method.
PU	The ability to have a bank of scenarios to test different strategies would make the system more useful.
AT	Software simulation of an exercise would be very good method for testing an emergency response plan rather than the tabletop role playing method.

8.2.3. Enhancing the User Experience Using Visual and Auditory Cues

Textual information describing the incident provided at tabletop role play exercises requires responders to visualise what the incident looks like, thus generating different perceptions of what they believed the was actually happening (BinSubaih et al., 2005). One participant stated:

"*You know you might turn around and I might say, this is the brief, and I've got in my head exactly what I think everybody's gonna see, but everyone around this table will see it totally different and make a totally different assumption. They act* *on their thoughts rather than what I mean. That's not what I wanted them to do, that's blown up.*"

The participants agreed that by allowing responders to rely on their imaginations of what they thought was happening at the scene may lead to people making assumptions (Appendix 12: Table 37). The scenarios developed for tabletop role play lack visual and auditory realism (Appendix 12: Table 37). The research participants felt that providing visual examples of real incidents with auditory cues would contribute to more realistic scenarios.

The participants described how the volume of sound resulting from a burst high pressure gas pipeline requires the wearing of protective ear equipment before the incident may be approached safely. The lack of sound representation in tabletop role play meant that responders may not be alerted to the need to wear protective ear equipment at the scene of an incident. One participant described how sound could be "the first thing that helps better our understanding [of an incident]".

In a comparison study of tabletop role play and software simulation for training in incident response, BinSubaih et al. (2005) found that visualization improves the responders' training experiences. BinSubaih et al. 2005, p.6) found that trainees "preferred the computer experiment" because they "managed to see things and live the incident more" during the software simulation through the use of visual cues. Participants in the BinSubaih et al. (2005) study also found that having a detailed software simulated visual representation, removed the burden of imagination that tabletop role play imposed.

The participants agreed that being able to visualise the scene of an incident would enhance the learning experience (Appendix 13; Appendix 15). The use of 3D models and animation to demonstrate the impact at the scene of an incident was shown to contribute to preparing first responders for what to expect when attending an incident. The participants thought that having the visual representation of the incident within the software presented everyone with the same view of the incident, allowing everyone to work with the same information. Participant 5 stated that the visual indicators used to represent the incident within the software simulation allowed users to “react more realistic than having to just imagine something”.

All participants agreed that the use of audio and visual cues during an exercise to display progress outcomes, consequences and feedback were thought to enhance the realism of an exercise, particularly in incidents involving high pressure gas pipelines. The benefits auditory and visual feedback bring to the enhancement of an exercise have been added as an item of PU to table 23 as shown in table 24.

Table 24 Opinions Relating to Software Simulation

Construct	Reason
PU	The ability to get immediate feedback enhances the learning experience.
AT	It would be much better to use the software simulation tool to run exercises for preparing responders in implementing a plan in an incident rather than the current method.
PU	The ability to have a bank of scenarios to test different strategies would make the system more useful.
AT	Software simulation of an exercise would be very good method for testing an emergency response plan rather than the tabletop role playing method.
PU	The ability to have auditory and visual incident feedback would enhance the exercise.

8.2.4. The Advantages of Remote Participation

Testing site evacuation and default activities such as responders moving posts, or performing their assigned role, was something the research participants felt tabletop role play could not achieve. Elements of disruption such as noise and lack of communication were also highlighted as experiences tabletop role play could not provide. The participants argued that during tabletop role play exercises, responders can communicate more easily than at a live incident, making the environment unrealistic. The lack of distractions tabletop role play afforded in comparison to a live incident was shown to contribute to the lack of realism within tabletop role play exercises.

During tabletop role play exercises responders are located within the same room, enabling responders to communicate with each other easily. Allowing responders to participate in an exercise from separate rooms or locations was something software simulation was shown to provide that tabletop role play could not. The ability to participate from separate locations is representative of how a live incident is controlled. Agencies such as NGN deal with the majority of the incident remotely from a centralised command centre, whilst having an operator onsite at the incident to convey information to other agencies. Running exercises simultaneously across multiple locations has been shown to reduce time and cost implications along with providing more flexibility with resources (Jain and Mclean, 2005).

A second benefit associated with having Bronze command staff participating in exercises from different rooms to Silver command, was that it might serve to create tension between the two levels of command. Participant 5 stated:

“The other thing I think it would be good for is creating a bit of tension between the operational people and the people back in the command room because you are getting all these calls wanting an update and its exactly the same as it was five minutes ago”.

Increased communication between responders has been shown to increase trust and improve team cohesiveness through shared experiences (Jain and Mclean, 2006, 2003; Churchill and Snowdon, 1998; Forester, 1989). Silver responders can use the discussion board to simulate the same demand for information updates from Bronze responders that they would in a live incident. Separating the different levels of command and allowing Silver command to demand information in this way was shown to put pressure on staff allocated to Bronze roles.

The research participants thought that the simulation would be useful for testing the communication flows from Bronze through to Silver or Gold commanders (Appendix 15: Figure 30). Different types of information can be made available to different types of users. For example, if a user logs into the system as FRS Bronze, they may be presented with a video detailing the scene of the incident, another user logged in as FRS Silver, may only get textual information to notify them that an incident was taking place. By making it the responsibility of the Bronze user to communicate the scene of the incident to the Silver user, the simulation can be used to test that flow of information. Studies have shown that the simultaneous training of personnel at different levels of the incident management hierarchy is demonstrated as a benefit attributed to distributed software simulation (Jain and Mclean, 2006, 2003; Churchill and Snowdon, 1998). The integration of training at different levels has been shown to improve team cohesiveness and performance (Jain and Mclean, 2006).

8.2.5. Removing Observers to Reduce Distraction

The amount of observers in the room where tabletop role play exercises are held was another issue participants associated with tabletop role play. The participants considered the amount of observers in the room to be a distraction and not indicative of a live incident environment (Appendix 12: Table 37). Having the potential to run a simulation remotely would remove the problem tabletop role play brings regarding too many observers in the room. By having users situated in different locations, observers could still watch what was happening during an exercise without having to be in the same room.

8.2.6. The Benefits of Online Collaboration

The research participants felt that one of the key benefits of tabletop role play was that it provided an opportunity for representatives from all emergency services to get together. The advantage of this was twofold: to put faces to names and to have an interchange of information on procedures and processes. The benefit of being able to put faces to names meant that relationships could be formed between agencies prior to an incident. Participants felt that the establishing of relationships in a safe environment contributed to facilitating the information flow at an incident. Forester (1989) found that increased communication between emergency responders, increased trust and reduced confusion, improving the emergency planning process. Responders who have had a chance to train together in tabletop role play exercises, provide a more effective response than those who come together for the first time at a live incident (Great Britain. Home Office Publications, 1998).

In a study applying the TAM to capturing opinions on internet based learning, Lee et al. (2005) recommend the use of online chat rooms to encourage collaboration suggesting that they create a sense of community. Lee et al. (2005, p.1102) imply that users “may be inherently motivated to feel connected to others within a virtual environment” and that “creating a virtual community of student users is therefore likely to improve motivation” towards using the system. A study of a virtual learning environment demonstrated that virtual communities of practice can compete with physical communities of practice Bird (2001). Stone (1992, p.507) describes virtual communities as “…passage points for collections of common beliefs and practices that unite people who are physically separated”.

The concept of virtual communities can be applied to generating a sense of community with emergency responders participating in an online simulated exercise to test emergency response plans. The discussion area within the software simulation offers an opportunity to discuss ideas and generate a sense of community, however this could be enhanced by introducing web cam and Voice Over Internet Protocol (VOIP) technologies such as Skype. Some of the participants were experienced in using Skype for work based activities. The study of the potential to embed Skype technology into the simulation is recommended for future research.

Communication and movement has emerged as a theme that can contribute to realism within an exercise to test emergency response plans. The ability to test communication flows from locations used within live incidents, has been shown to contribute to realism and development of staff competencies. The ability to test realistic communication flows between levels of command is an additional benefit software simulation brings to an exercise. There was a common agreement between the participants that the software simulation would improve operational (Bronze) staff performance and that it would be useful for tactical (Silver) staff (Appendix 14: Table 39). Table 25 shows the TAM constructs from table 24 with the addition of the items of PU associated with the advantages of communication and movement and the benefits the software simulation would bring to both tactical and operational responders.

Table 25 Opinions Relating to Software Simulation

Construct	Reason
PU	The ability to get immediate feedback enhances the learning experience.
AT	It would be much better to use the software simulation tool to run exercises for preparing responders in implementing a plan in an incident rather than the current method.
PU	The ability to have a bank of scenarios to test different strategies would make the system more useful.
AT	Software simulation of an exercise would be very good method for testing an emergency response plan rather than the tabletop role playing method.
PU	The ability to have auditory and visual incident feedback would enhance the exercise.
PU	Testing communication flows between different levels of command remotely located.
PU	Using the system would improve operational staff’s performance on the job
PU	Using the system would be useful for tactical people

8.2.7. Testing Emergency Response Processes

The results of the software simulation evaluation demonstrated a general agreement that tabletop role play did not allow responders to test the process of applying certain responses to the plan or incident (Appendix 12: Table 37). One participant gave the following example of being faced with a fire and ringing the emergency services 999 number:

"if you do a plan and we put that we're going to do some certain processes, like for example, you see a fire your gonna pick the phone up and your gonna make that 999 call. The tabletop exercise doesn't test that part of the process, of you actually being able to pick the call up and give 999 the information and that's what I'm talking about. So if I was sat there as a person well I'm gonna say I've seen the fire, I'm gonna immediately pick the phone up and I'm gonna ring 999. That tells me I know what the plan is, but it doesn't actually test the process of picking the phone up and ringing 999. Now if you've actually rang three 999 calls to the emergency services given them the information it's really difficult to do, so it doesn't actually test the process. So you know the plan because as I say I know I'm gonna do this, but you're not actually testing physically doing it.

The problem with this scenario is that the time it takes to make the call and the issues associated with making the call are not tested in a tabletop role play exercise. Whilst a responder knows they need to make the call because it is in the plan, the process of making the call is not tested. All participants agreed that tabletop role play exercises do not test actual response processes.

The software simulation allows exercise facilitators to make real-time responses to decisions made. If a responder submitted a response into the software simulated exercise to say they would ring 999, an exercise facilitator could respond to this decision in a number of ways, either by providing a written response in the discussion area or showing a textual, audio or visual response from the bank of existing scenarios within the software. The participants agreed that giving exercise facilitators the facility to provide real-time responses would enhance the realism of testing the processes by not allowing responders to just say what they would do and making them actively respond to the situation they were faced with in a variety of ways (Appendix 15: Figure 30).

8.2.8. The Benefits of Unrealistic Timeframes

Having a flexible timeframe was highlighted as an advantage tabletop role play brought to testing emergency response plans (Appendix 11: Table 36; Appendix 15: Figure 30). The ability to stop, start, rewind and review responses to activities was recommended as a benefit the software could emulate from tabletop role play (Appendix 13; Appendix 15). Although unrealistic, the feature allows the process to be sped up, so that responders spend time performing activities that enhance their learning rather than waiting for long periods performing mandatory activities. For example if an incident came to a standstill whilst gas engineers waited for a new part to be built, and there were responders from the Police that are manning the cordon areas during the time that the part is being built, you don’t need to simulate the waiting time during the exercise.

The lack of a realistic timeframe provides an opportunity to fit more activities in a shorter timeframe. Having the time to walk through plans during an exercise was indicated as a positive feature of tabletop role play. Table 26 shows the constructs from table 25 with the addition of being able to stop, start, rewind and review activities and decisions as an item of PU.

Table 26 Opinions Relating to Software Simulation

Construct	Reason
PU	The ability to get immediate feedback enhances the learning experience.
AT	It would be much better to use the software simulation tool to run exercises for preparing responders in implementing a plan in an incident rather than the current method.
PU	The ability to have a bank of scenarios to test different strategies would make the system more useful.
AT	Software simulation of an exercise would be very good method for testing an emergency response plan rather than the tabletop role playing method.
PU	The ability to have auditory and visual incident feedback would enhance the exercise.
PU	Testing communication flows between different levels of command remotely located.
PU	Using the system would improve operational staff's performance on the job
PU	Using the system would be useful for tactical people
PU	Being able to stop, start, rewind and review responses and activities.

8.2.9. A Decision Making Support Tool for Incidents

The ability to log decisions made during an exercise is a feature provided within the software simulation. The software is able to generate a report from the logged decisions to demonstrate that an exercise has been performed to test a plan in order to satisfy the legal requirements of both COMAH and PSR. A secondary benefit associated with recording data highlighted by the research participants was to use the decisions made within an exercise, as a tool to inform decision making during a live incident. Participant 4 stated:

"the important thing would be the decision making and why you've made certain decisions or why you haven't made certain decisions and if it's got that built in facility or consideration and you're going to use it as part of your exercise it would be silly not to use it in a realistic situation".

The same participant also claimed that the system provides "concise evidence of an exercise" to satisfy the legal requirements of both COMAH and PSR legislation. The ability to inform the decision making process at a live incident using data from the decisions made at an exercise, was perceived to be a significant benefit provided by the software simulation. A third benefit associated with recording the data was to use the data as proof that a decision had been tested and approved and therefore was justified in being used in a live incident. The log could also be used in response to an incident where HSE investigations required evidence of training records to test plans.

Half the participants agreed that being able to create an audit trail of the exercises, activities and responses would benefit training activities (Appendix 15: Figure 30).

The audit trail of responses and decisions would allow exercise facilitators to review the logs and assess where users required more training in certain areas. The participants thought that using an audit trail to inform training was an advantage the software simulation had over tabletop role play. There was a common agreement that the ability to review decision making was a benefit of the software simulation. Table 27 extends table 26 to show that being able to record, review and reuse decision data attributes are an item of PU associated with the software simulation.

Table 27 Opinions Relating to Software Simulation

Construct	Reason
PU	The ability to get immediate feedback enhances the learning experience.
AT	It would be much better to use the software simulation tool to run exercises for preparing responders in implementing a plan in an incident rather than the current method.
PU	The ability to have a bank of scenarios to test different strategies would make the system more useful.
AT	Software simulation of an exercise would be very good method for testing an emergency response plan rather than the tabletop role playing method.
PU	The ability to have auditory and visual incident feedback would enhance the exercise.
PU	Testing communication flows between different levels of command remotely located.
PU	Using the system would improve operational staff’s performance on the job
PU	Using the system would be useful for tactical people
PU	Being able to stop, start, rewind and review responses and activities.
PU	The system could improve training through providing a record of tested and approved decisions.
PU	The system could improve training by having an audit trail of responses and decisions that can be reviewed to assess where staff required more training.

8.2.10. Cost Effectiveness of Tabletop Role Play and the Proposed Software Simulation

Conflicting opinions were raised with regards to the cost effectiveness of tabletop role play exercises. For the LA, Police and FRS, tabletop role play was thought to be a cost effective approach to delivering exercises. It was viewed by these agencies that tabletop role play required few resources in terms of staff and equipment thus making it a cost effective option. Furthermore, tabletop role play was also thought to be cost effective by this group from the point of view that the organisation involved in the exercise did not have to suffer disruption to their business in order for the exercise to be executed (Appendix 11: Table 36).

Participants from NGN had opposing opinions to the rest of the group regarding the cost effectiveness of tabletop role play exercises. This group considered them to be expensive and not an effective utilisation of resources. One NGN participant explained how tabletop role play was costly to the COMAH organisation because they had to pay for:

- People to attend;
- The planning to run an exercise;
- The LA to plan and help develop exercises to test plans

Where an agency has multiple COMAH sites the LA associated with a site must develop the exercise to test the plan. Different LAs charge different rates to develop exercises (Appendix 12: Table 37).

Existing studies have shown that simulated virtual environments can be produced less expensively than reproducing full scale models, making them a more cost effective, accessible training solution (Jain and Mclean, 2006a; Su and Shih, 2003; Gibson and Howard, 2000; Howard et al., 2000). The Department of Defense found that using software simulated exercises could reduce training costs by 90% (Robinson, 2004). CVEs allow users to collaborate simultaneously across a distributed network from various geographical locations. Running exercises simultaneously across multiple locations, reduces time and cost implications associated with responders attending an event from a single location and provides flexibility in resource scheduling (Jain and Mclean, 2005). Table 27 has been expanded to show that software simulation contributes to PU through contributing to a cost effectiveness and flexibility in resource scheduling as shown in table 28.

Table 28 Opinions Relating to Software Simulation

Construct	Reason
PU	The ability to get immediate feedback enhances the learning experience.
AT	It would be much better to use the software simulation tool to run exercises for preparing responders in implementing a plan in an incident rather than the current method.
PU	The ability to have a bank of scenarios to test different strategies would make the system more useful.
AT	Software simulation of an exercise would be very good method for testing an emergency response plan rather than the tabletop role playing method.
PU	The ability to have auditory and visual incident feedback would enhance the exercise.
PU	Testing communication flows between different levels of command remotely located.
PU	Using the system would improve operational staff’s performance on the job
PU	Using the system would be useful for tactical people
PU	Being able to stop, start, rewind and review responses and activities.
PU	The system could improve training through providing a record of tested and approved decisions.
PU	The system could improve training by having an audit trail of responses and decisions that can be reviewed to assess where staff required more training.
PU	The system would provide a cost effective training solution that provides flexibility in resource scheduling.

8.2.11. The Portability of the Software Simulation Tool for Enabling Emergency Response Planning Exercises

Some solutions such as the Vector Command Suite require specialist equipment and transport to install the technology in different locations. The newly developed software simulation prototype is a portable solution that can easily be transported to any site and used independently of any network, without requiring specialist equipment or knowledge to implement the system. The software simulation tool uses a single laptop which acts as a server; other laptops can access the simulation via a router. The software simulation has been developed with the technologies to run across a wider network, but access to a network is required to test the solution further.

Running the software across a wider network would remove the issue of having to organise exercise participants in one place. In addition to improving logistics from a geographical perspective, responders could also log into the system and participate in an exercise whilst working from their current post. This would reduce costs to the COMAH organisation not only by allowing them to carry on with their work from their location during an exercise but also reduce costs associated with travelling to an exercise (Appendix 15: Figure 30). The way in which portability of the software simulation attributes to the PEU of the system has been added to the constructs from table 28 as shown in table 29.

Table 29 Opinions Relating to Software Simulation

Construct	Reason
PU	The ability to get immediate feedback enhances the learning experience.
AT	It would be much better to use the software simulation tool to run exercises for preparing responders in implementing a plan in an incident rather than the current method.
PU	The ability to have a bank of scenarios to test different strategies would make the system more useful.
AT	Software simulation of an exercise would be very good method for testing an emergency response plan rather than the tabletop role playing method.
PU	The ability to have auditory and visual incident feedback would enhance the exercise.
PU	Testing communication flows between different levels of command remotely located.
PU	Using the system would improve operational staff's performance on the job.
PU	Using the system would be useful for tactical people.
PU	Being able to stop, start, rewind and review responses and activities.
PU	The system could improve training through providing a record of tested and approved decisions.
PU	The system could improve training by having an audit trail of responses and decisions that can be reviewed to assess where staff required more training.
PU	The system would provide a cost effective training solution that provides flexibility in resource scheduling.
PEU	The system would be easy to set up and use.

8.3. Summary of the Key Findings from the Research

Nine key themes emerged during the analysis of the findings, these are shown in figure 23. The emergent themes are summarised in turn within this section.

. *Figure 23 Emergent Themes*

8.3.1. The Software Simulation Reduces the Time Responders Have to Prepare for an Exercise Response

Allowing responders' time to prepare for an incident within an exercise was one of the themes that emerged from tabletop role play that contributed to lack of realism (Appendix 12: Table 37). The progress bar used within the software simulation which demonstrates time elapsing was shown to increase pressure within users of the software. This pressure was required to encourage responders to make a decision more quickly, reducing the time they have to prepare and plan their responses to events. Providing real-time feedback and consequences in response to decisions made was thought to enhance realism and reduce the opportunity for responders to prepare and plan for incident events.

8.3.2. Feedback and Consequences are Used to Support Learning

Having the opportunity to provide feedback and consequences through real-time or a previously recorded bank of scenario responses, was shown to be useful in developing staff competencies in making decisions and applying the plan being tested (Appendix 15: Figure 30). Allowing responders an opportunity to practice decision making activities through the software simulation, can enable individuals to make decisions in a live situation. The software simulation tool allows a bank of scenarios to be stored within the database that can be used across multiple exercises. The same scenarios can be developed at different times of day to test the same plan in different situations, providing a more flexible approach to delivering emergency response planning exercises.

8.3.3. Auditory and Visual Cues are Used to Enhance the User Experience

The use of visualization to both set the scene of the incident and to provide feedback within the software simulation were shown to remove the burden of imagination from responders and enhance the realism of the incident (Appendix 15: Figure 30). The use of auditory cues afforded the responders with additional cues that contributed to the types of decisions and responses made at an incident such as the requirement for protective equipment against loud noise. Audio and visual cues provide more information to responders regarding an incident than a tabletop role play allows.

8.3.4. The Software Simulation allows Communication and Movement to be Represented

Tabletop role play allows responders to communicate in the same room and build relationships through face to face contact. Online discussion groups have also been shown to facilitate communities. Software simulation can be used as a CVE allowing people to be dispersed in different rooms using an online discussion board to develop a community between users. Embedding technologies such as Skype may bring added enhancement to facilitating and supporting the development of the emergency response community, however, further investigation into this feature is required.

The system has the potential to provide benefits associated with testing processes from within responders’ natural working environments, rather than meeting at a central location to participate in an exercise. Whilst the system has been developed with technologies to support this activity, using the system across a wider network still needs to be tested. Having this facility would enhance realism by allowing users to participate in their respective control rooms, which would improve training by allowing them to familiarise themselves with equipment in the control rooms. Participating in an exercise remotely via the software simulation would provide an opportunity for operational workers to participate in exercises. The software simulation was shown to be useful for testing the communication flows from Bronze through to Silver or Gold commanders (Appendix 15: Figure 30).

8.3.5. The Software Simulation Tests the Emergency Response Process

Simulating feedback and consequences to actions such as the 999, call are features the software provides that can contribute towards enhancing realism that tabletop methods don’t provide. Allowing exercise facilitators to provide real-time responses, has been shown to enhance the realism of testing the processes (Appendix 15: Figure 30). The use of real-time responses to decisions made, forces responders to actively respond to situations in a variety of ways rather than just stating how they think they would react and what they think the response to that action would be.

8.3.6. The Benefits of Unrealistic Timeframes

As with tabletop role play, the ability to stop, start, rewind and review responses and activities was recommended as a benefit the software could emulate (Appendix 13; Appendix 15).. Being able to speed up processes that don’t require responders’ response or interaction is a benefit of both methods.

8.3.7. The Software Simulation is a Decision Making Support Tool for Live Incidents

A range of benefits associated with using the data recorded within the software simulation to support decision making were identified (Appendix 15: Figure 30). There were four areas that this feature was thought to support the emergency response planning process:

1. The ability to log decisions made within the software simulation and generate a report to satisfy the legal requirements of both COMAH and PSR was a significant feature of the software. The system provides an audit trail of the type of organisations that attended an exercise and the decisions made and the exercise used.

2. The decisions made within an exercise could be used to inform decision making during a live incident.

3. The data recorded within an exercise could be used as proof that a decision had been tested and approved and therefore was justified in being used in a live incident. The log could also be used in response to an incident where HSE investigations required evidence of training records that showed plans had been tested.

4. Having an audit trail of responses and decisions was also thought to be useful for providing exercise facilitators with information on where users required more training in certain areas.

8.3.8. The Software Simulation is Cost Effective

The software simulation has been developed with technologies that allow exercises to be run simultaneously across multiple devices and locations. Allowing exercises to be run simultaneously across geographically dispersed locations can reduce time and cost implications associated with responders attending an event from a single location along with providing flexibility in resource scheduling. The ability to create and store a range of scenarios makes the software simulation a more flexible and cost effective approach to delivering emergency response exercises than tabletop role play.

8.3.9. The Software is Portable

The software is a portable solution that can easily be transported to any site and used independently of any network, without requiring specialist equipment or knowledge to implement the system (Appendix 15: Figure 30).

8.3.10. A Positive User Attitude Towards Using the System

All participants showed a positive attitude towards using the system. The final questionnaire issued to the participants contained the statement "*I think software simulation of an exercise would be good method for testing an emergency plan*", the response was captured using the 7 point Likert-type scale with anchors on strongly agree and strongly disagree. All participants agreed that using the software to run a simulation of an exercise was a good method for testing an emergency plan, figure 24 shows the results from the responses to this statement.

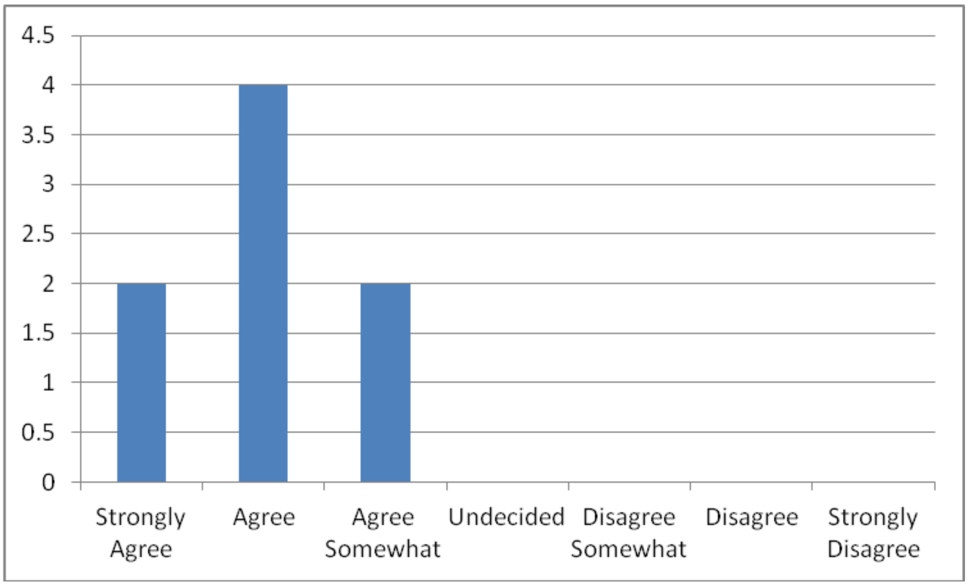

Figure 24 Participant's Attitudes Towards Using the System

Further detail was captured about each of the participant's responses (Appendix 17). The following reasons for strongly agreeing with the statement were provided by the participants:

"*The participant will be ready to make fast decisions in an incident, as he/she has good experience from the exercise. Adding realism will trigger participant to think back to how he conducted the exercise.*", (Participant 2, Appendix 17).

"*The system provides an opportunity to test understanding and feel pressures exerted from various areas during the management of an incident.",*(Participant 4, Appendix 17).

The interviews discussed in Chapter 6 conducted during exercise Cornerstone revealed that not having to respond to actions quickly was an issue with tabletop role play (Appendix 8). The research has shown that participant 2 considers the system will resolve this particular issue by "*making users ready to make fast* *decisions*". Furthermore participant 4 supports this finding by stating that the system "*provides an opportunity to test understanding and feel pressures exerted from various areas during the management of an incident*". Putting pressure on the decision makers to make decisions was another issue highlighted during the interviews at exercise Cornerstone. The responses from participant 2 and 4 above suggest that the system resolves this issue.

Those participants that agreed to the statement provided the following explanations for their attitude towards using the system:

"The system provides an understanding of the various types of incident and allows for checking actions, decisions in a safe environment. Cheap and safe with regards to training and development." , (Participant 1, Appendix 17).

"The participants could go through the actions of the plan and see and demonstrate any issues with the plan.", (Participant 5, Appendix 17).

Participant 1 describes how the system has demonstrated that it provides a facility for checking actions against decisions made, this was something revealed in the data captured from the brainstorming session held in phase 1 of the comparative evaluation, that tabletop role play did not achieve (Appendix 12: Table 37; Appendix 15: Table 30). Having a safe environment to check actions and decisions has been shown by Participant 1 to be a feature in favour of intention to use the software.

Two of the participants agreed somewhat to the statement regarding whether they thought the system provided a good method for testing an emergency plan. The reasons they gave for their responses are:

“Nothing can fully prepare you for an emergency situation i.e. noise, fire, explosion.”, (Participant 3, Appendix 17).

“Its only part of the whole package - realistic training could be used to enhance simulation but it’s a good start for future development.”, (Participant 6).

When questioned further both participants said that whilst they thought the system was a good method for delivering exercises to test emergency response plans, it should be used to complement other methods such as live role play rather than replace them.

A common agreement amongst participants was that whilst the application itself may not necessarily directly impact on the ability of Silver command staff to perform their role, the decisions that came out of the results of the exercise that were stored in the system would be useful for Silver command responders. Silver command job performance would be improved as an indirect result of the system rather than with a direct use of the system.

The findings show that 10 items of PU and1 item of PEU were identified by the research participants regarding the application of the software simulation prototype for emergency response planning exercises (Section 8.2.11, Table 29). Although AT using the system was not primarily under investigation within this study, 2 items of AT were revealed during the study. Figure 25 shows the key findings categorized with the TAM constructs PU, PEU and AT and the range of responses that support those findings.

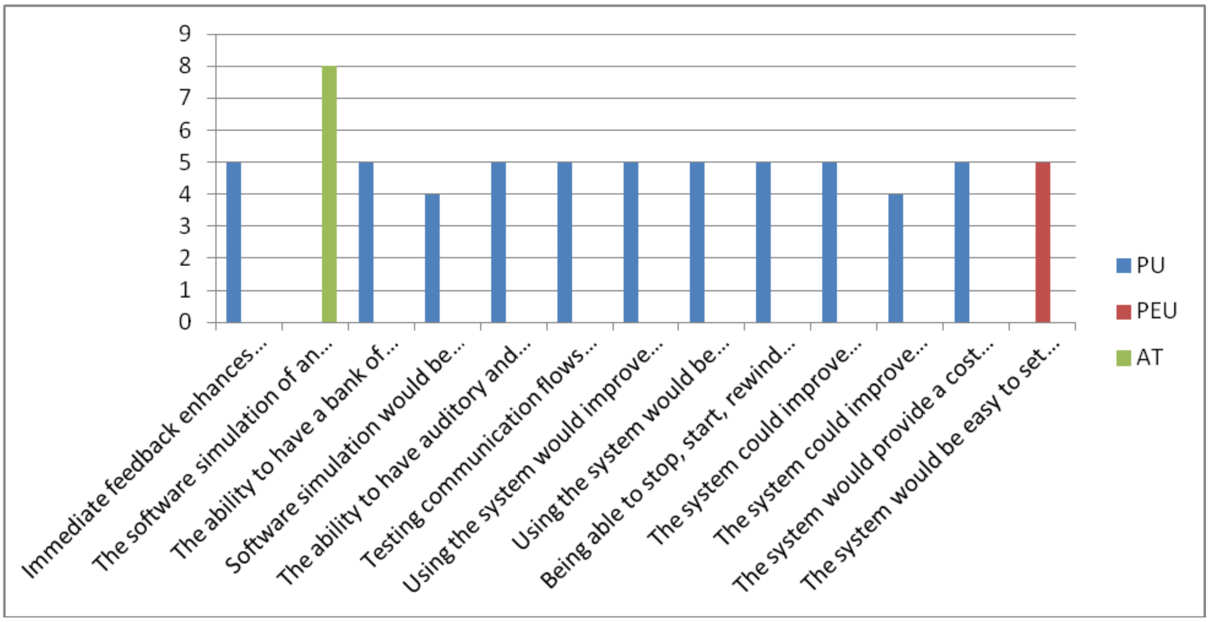

Figure 25 Key Findings Categorised as PU, PEU and AT

The study demonstrates that PU shows a greater response in the attitudes the research sample have towards using the system. Whilst PEU is shown to have a greater response in systems previously or currently used by the participants, PU has shown more frequently than PEU in the responses relating to those systems most commonly used (Figure 25; Appendix 18: Table 40). A number of studies show that PU is more significant than PEU in determining the acceptance and use of a system (Saadé and Bahli, 2005; Chau and Hu, 2001; Venkatesh, 2000; Chau, 1996; Keil et al. 1995).

A critical evaluation of emergency responders' attitudes and perceptions towards the application of software simulation, as a vehicle for testing emergency response planning strategies, indicates that this approach would be well received. Therefore virtual simulation would be accepted and used for testing emergency response plans in the UK gas industry.

Chapter 9 Conclusions and Recommendations for Future Work

This thesis served to evaluate the user acceptance of software to enable the testing of emergency response planning strategies in the UK gas industry. This has been achieved through addressing the objectives set out in Chapter 1. This chapter discusses how these objectives have been achieved and provides conclusions on the research findings.

9.1. Current Practice for Emergency Response Planning Exercises for High Pressure Gas Pipelines have been Examined and Documented

The background to the legislation that necessitates the need for developing emergency response plans and running exercises to test plans to satisfy COMAH legislation is discussed in Chapter 2. The legal and procedural requirements of training exercises for pipeline emergency plans have been presented. Methods currently used for conducting emergency response planning strategies have been examined and documented. Traditional methods include discussion, tabletop role play and live exercises. The issues current practice imposes include:

- The cost incurred by time and resource constraints of organising tabletop role play simulation exercises (Great Britain. Cabinet Office, 2010; Campbell et al., 2008; McGrath et al., 2005; Crichton and Flin, 2001).

- The complexity of organising exercises is time consuming and can require “several months” of planning to coordinate the availability of appropriate staff (Campbell et al., 2008; McGrath et al., 2005; Great Britain. Home Office Publication, 1998)

- The availability of emergency response personnel with the appropriate specialist knowledge required to participate in exercises (Hubbard et al., 2008).

- The lack of visual and auditory cues required to enhance training in scenarios designed for combat and Police training (BinSubaih et al., 2005; Lampton et al., 1995; Miller and Thorpe, 1995).

9.2. Software Simulation as a Tool for Facilitating the Testing and Training of Emergency Response Planning Exercises has been Investigated and Reviewed

The potential virtual simulation offers the testing of emergency plans has been examined in Chapter 3. Software simulation is currently applied in industry where a controlled environment that allows decisions and responses to be audited and mistakes made without serious consequence is required (Smith and Carter, 2010; Tichon et al., 2003; Haller et al. 1999). The literature revealed that technology can allow exercises to be run simultaneously across multiple locations, providing opportunities for a wider range of participation (Churchill and Snowdon, 1998). Furthermore software simulation strategies can be used to enhance training and offer alternative opportunities to tabletop role playing methods (Jain and Mclean, 2006a; National Research Council, 2002).

The application of software simulation is exercised for activities and situations such as combat, flight training or emergency scenarios (Smith and Carter, 2010; Tichon et al., 2003; Haller et al. 1999; Miller et al., 1995). The adoption and application of software simulation for the development of response and applied skill in industries such as aviation, military, medicine and the emergency services has been discussed (Grant and Meadows, 2008; Macedonia, 2002; Crane et al. 2001; Huddlestone et al., 1999; Messina et al. 1997; Lampton et al., 1995).

The literature has shown that software simulation provides a controlled and cost effective method for conducting training activities where live training could be dangerous or costly. Improved competence, increased cohesiveness and effective team incident management are all attributed to using software simulation for learning. The ability to test a wide range of repeatable scenarios is a benefit the literature has shown software simulation can provide. Distributed CVEs have also been shown to provide greater flexibility through providing access to participants that are geographically dispersed.

9.3. Frameworks and Qualitative Methods for Capturing, Measuring and Evaluating, User Acceptance of Software Simulated Emergency Response Strategies have been Identified and Reviewed

Chapter 4 presents a discussion on technology acceptance theory. The evaluation framework presented by the TAM and its underlying theory the TRA has been described. The methods, evaluations techniques and limitations of the TRA and the TAM have been examined and existing studies applying the frameworks reviewed. This research served to measure the perception and intention to use the proposed prototype rather than the use of a fully implemented system. A deconstructed model of the TAM containing the following elements has been applied to this study: perceived ease of use, perceived usefulness, behavioural intention to use and attitude towards using. Existing research has demonstrated that whether the TAM or a modified version of the TAM is used, reliable results can be achieved without capturing and evaluating all constructs defined within the model (Legris et al., 2002; Fetscherin and Lattemann, 2008).

9.4. A Virtual Simulation Prototype with which to Perform the Evaluation Study has been Developed and Refined

A methodological approach for developing a virtual simulation prototype has been described in Chapter 6. The UP is the software methodology that was applied to the development of the prototype. The software was designed and developed using UML tools and techniques. Each phase of the software development process, from the requirements capture through to the development of the final prototype used for the study, is documented within Chapter 6. The software requirements were developed in collaboration with NGN. The case study of existing methods and practice for conducting emergency response exercises informed the design and development of the software simulation prototype. A pilot study was performed to test both the research approach and the prototype. Both the prototype and research methods were refined as a result of the pilot study.

9.5. The Virtual Simulation Prototype has been Evaluated and Compared with that of Traditional Methods for Testing Emergency Response Planning Strategies

The research methodology undertaken in this thesis is described in Chapter 5. The software simulation prototype was evaluated using a triangulation of methods. A combination of interviews, questionnaires, observation and participatory research techniques were used for the evaluation. The data capture process for gathering opinions and perceptions on both current practice and software simulated methods for conducting emergency response exercises is described in Chapter 8. A deconstructed version of the TAM provided the theoretical framework that guided the development of the research instruments, used to measure participants' perceptions.

9.6. User Acceptance of a Virtual Simulation for Testing Emergency Response Planning Strategies in the UK Gas Industry has been Evaluated

A comparative user evaluation of tabletop role play and software simulation methods for testing emergency response plans is discussed in detail in Chapter 9. The emergent themes resulting from the NVivo analysis are discussed in terms of PU and PEU for both tabletop role play and software simulation. The key findings are examined and the extent to which TAM explains intention to use the software is discussed.

9.7. A Discussion on the Key Findings from the Research

The findings from the study have been described, the data analysed and the perceptions and opinions of the research participants considered. The research has shown that the research sample are in favour of using the software simulation to deliver and test emergency response planning strategies. Thirteen key findings support this claim, these are:

1. The ability to have auditory and visual incident feedback would enhance the exercise.

2. The ability to have a bank of scenarios to test different strategies would make the system more useful.

3. The ability to get immediate feedback would enhance the learning experience.

4. Testing communication flows between different levels of command remotely located enhances the realism of the exercise.

5. Using the system would improve operational staff job performance.

6. Using the system would be useful for tactical people.

7. Being able to stop, start, rewind and review responses and activities it is a beneficial feature of the system.

8. The system could improve training through providing a record of tested and approved decisions.

9. The system could improve training by having an audit trail of responses and decisions that could be reviewed to assess where staff required more training.

10. The system would provide a cost effective training solution that provides flexibility in resource scheduling.

11. The system would be easy to set up and use.

12. Software simulation of an exercise would be a good method for testing an emergency response plan.

13. Software simulation of an exercise would be better than the current method for preparing participants for implementing a plan in an incident.

Software simulation has shown to enhance training activities that may be too dangerous or costly to train in a live situation. The literature has shown that conducting training activities using software simulation can enhance user's confidence in responding to live situations. Distributed learning poses different benefits and challenges to face to face learning, the literature relating to these differences have been investigated. The literature has shown that software simulation can enhance learning and that CVEs bring benefits to training distributed groups. The literature shows that software simulation provides a controlled and cost effective method for conducting training activities where live training would be dangerous or costly. Improved competence, increased cohesiveness and effective team incident management are all attributed to using software simulation for learning. Software simulation provides the ability to test a wide range of repeatable scenarios. Distributed CVEs provide greater flexibility through providing access to participants that are geographically dispersed. The perception individuals have about technology can influence whether or not the technology is accepted. The theoretical framework provided in the TAM underpins the methodological approach taken in this study.

A deductive approach using a triangulation of research methods has been used to investigate and evaluate the virtual simulation tool for emergency response planning exercises. A case study of existing methods and practice for conducting emergency response exercises has informed the design and development of the software simulation prototype. A combination of interviews, questionnaires, observation and participatory research techniques have been used to capture data regarding current methods and the proposed software simulation. The software methodology and approach to developing the prototype to be used for the study has been described.

9.8. A Critique of the Research

This section reflects on the research process undertaken in this study and considers a different approach to the research. The main items considered include defining the scope of the research and the methodological approach.

9.8.1. Defining the Scope of the Study

This research includes many elements for consideration. An element of the study was to understand the health and safety legislation that surrounds the requirement and application of emergency response planning strategies. A second element of the study was to design and develop a virtual simulation prototype to evaluate the potential acceptance and use of the prototype for testing emergency response planning strategies. Virtual software simulation technologies have been investigated and approaches to technology acceptance evaluation frameworks considered. Each of the topics investigated during this study has the potential to be a PhD study on their own.

Defining the scope of the study was one of the most challenging aspects of this research. As is the nature of a PhD learning to recognise the theories and concepts that are applicable to the study is part of the process. Having a clearly defined scope at the onset of the research and a methodical approach to maintaining within the restrictions imposed by that scope may have provided a more direct journey through the project.

The scope of both the research and the development of the prototype was challenged half way through the PhD project when the point of contact at the collaborative research organisation changed. Having a new point of contact brought new ideas and expectations from the organisation in relation to both the prototype requirements and the research being undertaken. This generated new or amended requirements within the software which increased the workload associated with the software development aspect of the study. It is recommended that a scope that includes some flexibility for changes during the research project is agreed early on in with all parties in the research process.

9.8.2. A Critique of the Methodological Approach

A methodological approach that combined a triangulation of research methods was applied to this study. The method produced rich and valuable data which provided detailed insights into the experiences and perceptions emergency responders have regarding the emergency response planning process. It was not clear at the onset of the research however how the data would be organised and used. Some of the early observational sessions and interviews held within the case study of existing tabletop role play exercises would have benefited from a more methodical approach to capturing and organising the data.

The Technology Acceptance Model was used as a framework to inform the presentation of the analysis. Many of the TAM constructs were difficult to evaluate on the prototype. Although the TAM was developed to evaluate software prototypes (Davis et al., 1989; Davis, 1980), a further study of the system being used will need to be performed to investigate the TAM constructs attitude towards using and behavioural intention to use the software simulation in further detail.

Applying the TAM to one or more evaluations of the virtual simulation being applied to testing emergency response planning strategies would provide further opportunities to evaluate emergency responders' attitudes towards using and behavioural intention to use the software simulation.

Existing studies implementing the TAM have been shown to demonstrate validity in their data through statistical analysis (Betrand and Bouchard, 2008; Fetscherin and Lattemann, 2008; Lee et al. 2003; Lee et al. 2005; Davis et al., 1992; Davis et al. 1989). The sample size used in this study is indicative of a representative sample of emergency response exercise participants producing qualitative rather than quantitative results. Participatory methods were used to gather rich detail about user opinions of the software as opposed to gathering information for statistical analysis. Applying the TAM to longitudinal studies of evaluating the application of the software simulation for testing emergency response planning strategies would provide quantitative data that could be analysed statistically. The findings from the statistical analysis could be comparatively evaluated against other studies that have applied the TAM. A statistical comparison such as this would validate the rigour of the methodological approach.

A critique of the study has been considered in this section, recommendations for conducting further research in this area in response to the critique include:

1. Defining the scope of the study at the onset of the research and creating a methodical approach to maintaining within the restrictions imposed by that scope.

2. Having the scope of the study clearly documented and agreed early on in the research process with all parties that have an interest in the research.

3. Developing a scope that includes some flexibility for changes during the research project.

4. A longitudinal study of the system being used to test emergency response planning strategies would provide data that could be used to validate the results from this PhD research further. A longitudinal study would also allow the TAM constructs attitude towards using and behavioural intention to use to be analysed more rigorously.

9.9. Recommendations for the Future Development of the Software

Recommendations for the future development of the software prototype proposed throughout the case study were made with regards to enhancing the user experience and improving the ability of the software to allow emergency response planning strategies to be tested. These recommendations include:

1. Making the software facilitator oriented so that the exercise facilitator can provide different responses to decisions to different users rather than having the same information shown to all users in response to a decision.
2. Inclusion of a media resource section that could be used to show visual information such as images of the incident via the media section.
3. A ticker tape style message to display media information. This would be similar to a Sky news reel. The text on the ticker tape message would display text submitted by a user playing the role of a media representative.
4. Inclusion of an interactive map. An interactive map would allow participants to draw items such as exclusion zones, road blocks and other details relevant to the incident on the map. The ability for users to be able to add items to the map

and for the map to be updated on all screens was favoured by all participants. It was believed that this would emulate what happens in a real incident with printed maps. An interactive map would provide a further unique element to the proposed solution to enhance the realism of an exercise.

5. Developing the system further to allow responders to participate in an exercise remotely.

Each of these items are outwith the scope of this study and as such are recommended as future developments of the system.

9.10. The Contribution to Knowledge

The research contributes to original knowledge in a number of ways. The review of the literature research in Chapters 2 and 3 reveal that the application of software simulation to facilitate emergency response planning strategies would enhance the process. Both the literature review in Chapter 3 and the requirements analysis in Chapter 6 demonstrate that whilst many existing technologies are available for training in emergency scenarios, none satisfy all the requirements needed to facilitate emergency response planning strategies for UK gas infrastructure. A novel software simulation prototype for the testing of UK gas pipeline emergency plans has been developed in response to this need.

The prototype has been used to facilitate an investigation into a comparative evaluation of software simulation and traditional tabletop role play as methods for executing emergency response planning strategies. Chapter 8 discusses the results of the investigation and contributes to knowledge through the development of a critical comparative understanding of user perceptions of software simulation, as a mechanism for training in gas pipeline emergency response. The TAM is the theoretical model that underpins the approach to the evaluation and is used to organise the emergent themes from the analysis. The application of the TAM to evaluate user acceptance of a virtual simulation tool as a method for conducting emergency response planning strategies is a novel application of this model.

The potential application of software simulation has been investigated in the original context of testing assets in the gas infrastructure to satisfy legislative requirements. The conclusion of the thesis is that emergency responders would accept and use a virtual simulation tool to perform emergency response planning exercises. This research has stimulated innovation within the attitudes of emergency responders towards testing and developing emergency plans in the UK gas industry. As shown in Chapter 8, the participants realised the potential of the system not only to facilitate the emergency response exercise process, but also to demonstrate an innovative approach to providing “concise evidence of an exercise” (Participant 2, Appendix 17) not only to satisfy the legal requirements of both COMAH and PSR legislation but also to defend the decisions been made at a live incident. As Participant 5 stated:

“*the important thing would be the decision making and why you’ve made certain decisions or why you haven’t made certain decisions and if it’s got that built in facility or consideration and you’re going to use it as part of your exercise it would be silly not to use it in a realistic situation”.*

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Appendices

Appendix 1 : Abbreviations

ACMH	Advisory Committee on Major Hazards
AI	Attitude towards Intention
ARPA	Advanced Research Projects Agency
BI	Behavioural Intention
CAVE	Cave Automatic Virtual Environment
COMAH	Control of Major Accident Hazards 1999
CVE	Collaborative Virtual Environment
FRS	Fire Rescue Service
GUI	Graphical User Interface
HMD	Head Mounted Displays
HSE	Health and Safety Executive
LA	Local Authority
NGN	Northern Gas Networks
OMG	Object Management Group
OO	Object-Oriented
PEU	Perceived Ease of Use
PU	Perceived Usefullness
PSR	Pipeline Safety Regulations 1996
SIMNET	SIMulator NETworking
TAM	Technology Acceptance Model
TRA	Theory of Reasoned Action
UK	United Kingdom
UML	Unified Modelling Language
UP	Unified Process
VE	Virtual Environment
VR	Virtual Reality

WOZ	Wizard of Oz

Appendix 2: Glossary

Attitude towards Intention	An individual's positive or negative evaluative affect about performing a specific behaviour.
Behavioural Intention	Behavioural Intention towards using a system.
Bronze	A role that operates at operational level such as a Police Constable.
CAVE	Cave Automatic Virtual Environment – a technology that is used to developed fully immersive environments.
Class Diagram	A structural diagram provided within the UML for modelling objects within a system.
Collaborative Virtual Environment	A virtual environment that supports collaborative activities between users that are geographically dispersed.
COMAH Operator	An organisation bound to the Control of Major Accident Hazards 1999 regulations.
COMAH Site	Locations that the Control of Major Accident Hazards 1999 apply to.
Desktop software simulation environments	A simulated environment that can be experienced on a desktop PC.
Fully immersive environment	An environment that is designed to immerse the user completely in the activity they are performing. For example a full mock up of a flight cabin used to train pilots to fly.
Gold	A role that operates at a strategical level such as government ministers.
High-Fidelity Prototypes	Prototypes developed using software.
Hydra Immersive Simulation System	A software simulated environment that allows real-time simulation of incidents.
Lo-Fidelity Prototypes	Prototypes developed using simple techniques such as hand drawn sketches on paper.
Major Incident	A significant event that demands a response beyond the routine (Health and Safety Executive 2010a).

Minerva System	A system developed to support team-based decision making.
Object-Oriented	An approach to developing software systems that model real-world objects.
Off-Site Plan	A plan which contains all the details required in the event of an incident at a COMAH site that is held off-site from the COMAH site.
On-site Plan	A plan which contains all the details required in the event of an incident at a COMAH site that is held on-site at the COMAH site.
Perceived Ease of Use	The degree to which someone believes using a system would be free from effort.
Perceived Usefulness	The degree to which someone believes that using a system would enhance their job performance.
Seveso Directive	Sets out health and safety legislation relating to the transportation and storage of hazardous material within Europe.
Silver	A role that operates at a tactical level such as Chief Inspector of Police.
Unified Modelling Language	Standard notation for developing Object-Oriented systems.
Unified Process	Software methodology that uses the Unified Modelling Language to develop Object-Oriented systems.
Use Case Diagrams	A notation provided within UML for capturing requirements.
Virtual Environment	Environments that allow virtual reality activities to take place.
Virtual Reality	Activities that take place in a software simulated environment.
Wireframes	A software technique used to model the structure and flow of information within a system.
Wizard of Oz Approach	An approach to prototyping whereby the system looks like a fully functioning system but only partly works.

Appendix 3: Sample Emergency Response Plan

This appendix includes an example of a COMAH onsite emergency response plan.

Plans contain data that is sensitive and unable to be published in a public domain.

The sensitive data within this plan has been removed inline with Northumbria University’s ethical policy and procedure for presenting sensitive data in research.

COMAH

ONSITE EMERGENCY PLAN

<<Name of COMAH Site>>

HIGH PRESSURE GAS

STORAGE SITE

Copies to:

1. <<Name of Site>> (PRS)
2. Area Operations Manager (Maintenance)
3. Network Integrity - <<COMAH Operator>>
4. Emergency Incident Facility - <<Location Details>>
5. Emergency Incident Facility - <<Location Details>>
6. System Control
7. <<Location of site >>
8. United Utilities Communications Department
9. Local Authority EPU

REMOVE and DESTROY

Any On-Site Emergency Plans previous to this issue

January 2010

CONTROL OF MAJOR ACCIDENT HAZARD REGS 1999

MAJOR ACCIDENT HAZARD ON-SITE EMERGENCY PLAN

COMAH

ON SITE EMERGENCY PLAN

<<COMAH SITE>>

HIGH PRESSURE GAS STORAGE SITE

LOCATION	<<Location Details>>
CATEGORY	**COMAH SITE**
SYSTEM	**Natural Gas Storage Site**
TITLE	**On-Site Emergency Plan**

DOCUMENT CUSTODIAN: All requests for changes or perceived problems with operation of this document must be referred to the Document Custodian.	**Network Integrity and Standards Manager** <<COMAH Operator>>

On receipt and signature of this copy of the On Site Emergency Plan, all previous copies must be removed, destroyed and replaced within 7 working days.

COPY No: 2	**SIGNATURE OF RECIPIENT:**
ISSUED TO:	**DATE:**

DOCUMENT RECORD

REV No.	DATE	REMARKS	AUTHOR(s)	REVIEWED	APPROVED
1	Dec 99	Annual Review	J. Bloggs	M. Brown	J. Doe
2	Dec 00	Annual Review	M. Brown	J. Bloggs	J. Doe
3	Jan 02	Annual Review	M. Brown	J. Bloggs	J. Doe
4	Oct 02	Review	M. Brown	J. Bloggs	J. Doe
5	Dec 03	AN. Other	J. Doe	J. Bloggs	
6	Jun 06	AN. Other	Network Maintenance/ Network Integrity	Network Integrity & Standards Manager	
7	Sep 07	Annual Review	AN. Other	Network Maintenance/ Network Integrity	Network Integrity & Standards Manager
8	Feb 08	Revised <<COLLABORATING AGENCY>> document	AN. Other	J. Bloggs	Network Integrity & Standards Manager
9	Jan 10	Review	Some Engineering	AN. Other	Network Integrity & Standards Manager

CONTENTS

APPENDIX F: SITE ISOLATION VALVES

APPENDIX G: TECHNICAL DETAILS OF EQUIPMENT ON SITE

APPENDIX H: ENVIRONMENTAL PLAN

APPENDIX I: ALARM ALERT PROCEDURE

APPENDIX J: <<COLLABORATING AGENCY>> PROCEDURE CFS-018

1. INTRODUCTION

Example text:

Under the COMAH Regulations, operators of Top Tier COMAH Sites must prepare adequate Emergency Plans for dealing with the on-site consequences of possible major accidents and provide assistance with off-site mitigation actions.

Emergency planning is a key element in the safety management of gas storage sites. The principal objective of this Emergency Plan is to identify management roles and responsibilities and the procedures to be implemented in the event of an unplanned gas release resulting in an emergency at this site.

This Emergency Plan complies with <<COMAH Operator’s>> emergency planning procedures for the <<COMAH Site>> natural gas storage site at <<Location>>. The preparation of this Emergency Plan has been based on the guidance given in HSG 191 - Emergency Planning for Major Accidents.

This Emergency Plan together with the <<COMAH Site>> Safety Report forms the basis of consultation with the <<Local Authority>> Emergency Planning Unit and the Emergency Services leading to the production of an Off-Site Emergency Plan.

Employee representatives, Emergency Services, the Environment Agency and the Emergency Planning Authority have been consulted on the contents of this Emergency Plan.

The following items are considered essential information for the effective implementation of this On-Site Emergency Plan:

Section 11	Task Cards
Appendix B	**Call out details**
Appendix C	**<<COMAH Operator>> Emergency Response Organisation**
Appendix D	**Maintenance and E&I structure**
Appendix E	**Hazard Distances & Plans**
Appendix F	**Site Isolation Map**

RESPONSIBILITIES

The Network Operations Director for <<COMAH Operator>> has specific responsibility for safety management of the <<COMAH Site>> site.

The Network Integrity and Standards Manager (<<COMAH Operator>>) is responsible for drawing up the Emergency Plan for the <<COMAH Site>> site.

Emergency response provision is provided by <<collaborating agency>> Head of E&I & Maintenance. The <<collaborating agency>> Head of E&I & Maintenance is accountable for delivery of this emergency response.

3. ORGANISATION OF THE EMERGENCY RESPONSE

The <<COMAH Operator>> Incident Response Organisation together with a schematic demonstrating how a reported incident is dealt with is shown in Appendix C.

The Network has staff on standby at all times capable of dealing with incidents on gasholders, pipelines and regulating equipment. Standby rotas for emergency personnel are arranged on a geographical basis within the Network to minimise response times.

3.1 Detection of an Incident at <<COMAH Site>> Gas Storage Facility

The <<COMAH Site>> site is operated remotely by the System Control using a radio link. Various analogue/digital values and the status of various items of plant and equipment are relayed to System Control. System Control monitors a considerable range of operating parameters on site and deviations from normal operation of equipment may be detected by abnormal pressures or equipment parameters.

3.2 Warning

The <<Local Authority>> Emergency Planning Unit Off-Site Emergency Plan includes a <<COMAH OPERATOR>> Communication Strategy on how the public in the vicinity of the <<COMAH Site>> Site will be alerted in the event of an accident. <<COMAH OPERATOR>> Communications Department will manage the issue of all relevant information/instructions to the public and media during the incident.

Information on any incident would be broadcast to the public by **BBC TEES on 95FM**. (http://www.bbc.co.uk/iplayer/playlive/bbc_tees/)

3.3 Reaction of Personnel

In order to ensure a consistent and comprehensive response to a major accident on the <<COMAH Site>>, a series of Task Cards are provided that define the duties and responsibilities of Site Incident Controller, Incident Controller etc. (see Section 11.0 for the Task Cards and Appendix B for the relevant contact details).

3.4 Incident at Third Party Location (Domino Establishment)

There are 2 “Domino Establishments” and 5 Site Neighbours within the Public Information Zone of the <<COMAH Site>> Site. Contact details for these establishments in the event of an incident on site are given in Appendix B.

Where two or more Companies have been designated as Domino Establishments the Operators of those sites must take into account the overall hazard.

An incident at a third party location can be detected on the <<COMAH Site>> PRS Site and Wellheads by warning sirens.

In the event of a Third Party Emergency follow the instructions detailed in the Alarm Alert Procedure shown in Appendix 9.

3.5 Notification of an Incident

An incident at the site may be reported by Network personnel or the Emergency Services to either <<COMAH OPERATOR>> System Control or Dispatch Services or by a member of the public to the National Gas Emergency Call Centre.

Any reported incident would initially be dealt with by the <<COMAH Operator>> Dispatch Services, (see Appendix 3, Figure 3.1).

<<COMAH Operator>> Incident Response organisation is shown in Appendix C, Figure 3.2.

<<COMAH OPERATOR>> System Control, Dispatch Services and the National Gas Emergency Call Centre are permanently manned.

3.6 Initial Response to an Incident

The first report back to <<COMAH OPERATOR>> System Control or Dispatch Services from the site will establish whether Emergency Services are required to attend the incident. If they are required, it is the responsibility of <<COMAH OPERATOR>> System Control or Dispatch Services to immediately call each Emergency Service as required or confirm they have been contacted, see Appendix C.

During normal working hours a Network manager within the Network has responsibility for control of incidents and emergencies.

Incidents and emergencies that occur outside normal working hours are controlled by the Duty Standby Manager. Standby personnel can be contacted by home or mobile telephone, which allows resources to be mobilised.

3.7 Site Incident Controller

In the event of an emergency being declared, a Site Incident Controller is appointed to take charge and co-ordinate activities to deal with the emergency on site.

The most senior manager on site can initiate this site Emergency Plan at the time of an incident. They will then assume the role of Site Incident Controller and inform the Head of E&I & Maintenance, or their nominated deputy, as shown in the Maintenance & E&I Structure in Appendix D <<collaborating agency>>.

Outside normal working hours, the on-call Standby Duty Engineer will attend the incident and once they arrive on site will assume the role of Site Incident Controller.

The Site Incident Controller, via the Incident Controller, will request appropriate personnel to attend site to institute the necessary control measures and maintain effective liaison with the Emergency Services on site and the public.

<<COMAH OPERATOR>> System Control holds duty rosters for all Network Maintenance staff together with their home and mobile telephone numbers.

3.8 Incident Controller

The Head of E&I & Maintenance, or their nominated deputy, will proceed to an <<COMAH OPERATOR>> Incident Control Room, either at <<Location>> or <<Location>>. On arrival at the Incident Control Room he will assume the role of Incident Controller and immediately contact the Site Incident Controller.

The Incident Controller will advise the Network Operations Director (<<COMAH OPERATOR>>) and Operations Director <<collaborating agency>>, or their nominated deputies, of any incident or emergency that requires the site Emergency Plan to be initiated.

Depending on the nature of the incident it may be necessary to set up a Control Room to support and co-ordinate the overall emergency response (e.g. Network Planning, off-site response).

As stated in <<COMAH OPERATOR>>/PR/E/3, the Incident Controller will decide whether or not the Operational Command (Bronze) is able to deal with the situation without a Tactical Command (Silver) being convened, as shown below:

Command Level	Area of operation	Example of position
BRONZE	**OPERATIONAL** On Site with possible support from Incident control Centre	Network Officer (NO) Network Operations Manager (NOM) Area Operations Manager (AOM)
SILVER	**TACTICAL** Normally at Incident Control Centre (<<Location>>)	Area Operations Manager (AOM) Maintenance Operations Manager Head of E&I & Maintenance
GOLD	**STRATEGIC** Corporate decisions	Operations Director (<<COLLABORATING AGENCY>>) Network Operations Director (<<COMAH Operator>>) Chief Executive Officer (<<COMAH Operator>>)

5. CONTACT WITH EMERGENCY PLANNING UNIT

5.1 When?

In the event of a major emergency, or an uncontrollable incident which could reasonably be expected to lead to a major emergency.

5.2 How?

Contact details for the **<<Local Authority>> Emergency Planning Unit** are shown below. Full contact details are given in appendix B.

During Office Hours	<<Telephone Number>>
Out of Hours Duty Emergency Planning Officer	<<Telephone Number>>

Information to be passed to Emergency Planning Authority

- Identify yourself.
- Declare a major incident in progress.
- Identify location of incident within site boundaries.
- Briefly describe nature of incident.
- Briefly describe steps taken to date.

5.4 Local Authority Liaison

The Network Support Manager (HS&E), or his nominated deputy, will have responsibility for liaising with the Local Authority responsible for preparing the Off-Site Emergency Plan.

5.5 Communications Department

Contact the Network Communications Department immediately an On-site Incident has been declared. See Appendix B for contact details.

6. NOTIFICATION OF MAJOR ACCIDENTS

6.1 Major Accident Definition

An occurrence i.e. a major emission, fire or explosion, as a result of an uncontrolled series of events during an industrial activity which leads to a serious or potentially serious danger, immediate or delayed, to people or the environment inside or outside the installation and which involves one or more dangerous substances.

6.2 Competent Authority

Any major accident on site must be reported to the Competent Authority as soon as possible. There must also be written proof (fax) of this notification. Contact details are given in Appendix B and below as follows:

HSE	<<Contact name and address>>	<<Contact telephone numbers>>
Environment Agency	Contact with the EA must be made by Environmental Team – see Environmental Emergency Response Plan for contact details. 24 Hour Incident Hotline Enquiries	<<Contact telephone numbers>>

7. SITE ACCESS SAFETY PROCEDURES (PRS & WELLHEADS)

It is essential that all <<COMAH OPERATOR>> Personnel and Contractors working at or visiting the PRS Site or Wellhead Locations are registered at the <<collaborating agency>> Control Centre before commencement of any work and have been issued with a 2 way communication radio or have access to one (Refer to Procedure CSF-018 shown in Appendix J).

To enable registration all personnel including short term visitors must have attended the appropriate <<COLLABORATING AGENCY>> Induction Briefing and received a valid pass. Short term visitors must be accompanied at all times by an <<COMAH OPERATOR>> Authorised Person.

System Control must be notified both on arrival at and departure from the site.

8. INCIDENT SCENARIOS AND PLANNED RESPONSES

The evacuation of personnel and protection of plant on the site should be considered before any actions detailed in the following sections are taken to stop and make safe a release.

The COMAH Regulations Safety Report produced for the <<Location>> site identifies a number of events that could lead to an accident at the site. The events range from those that are foreseeable and relatively low consequence to low probability, higher consequence events. Both a foreseeable, relatively low consequence event and a low probability higher consequence event are described below, along with the appropriate strategies for dealing with the events and limiting the consequences. Hence the full range of possible events is considered. The general public or personnel on site at the time of any incident may detect these events.

Instrumentation is used to monitor the operation of plant and equipment on the site. Deviations from normal operating parameters will be alarmed in System Control and result in on-site investigation or remote isolation of the cavities via System Control. Although the site is unmanned it is visited regularly by Operations staff and up to 8 people could be on site. All people visiting site are required to register at the <<COLLABORATING AGENCY>> Control Centre and notify System Control both on arrival and departure. The <<COLLABORATING AGENCY>> procedure CSF-018 is shown in Appendix 10.

The <<COMAH OPERATOR>> Procedure on Safe Control of Operations sets out the overall minimum requirements for systems, procedures, training, record keeping and monitoring for Safe Control of Operations on operational and non operational sites and is intended to assist Network personnel to determine the appropriate action needed to ensure that all operations on the <<COMAH Operator>> Network are carried out safely, and in compliance with all relevant current legislation.

When dealing with an uncontrolled release of natural gas the priorities are;

1. Safeguard life

2. Safeguard property

3. Locate and stop/minimise the release

In the event of an uncontrolled release of natural gas, a key objective is to minimise the quantity of gas released by isolation of the affected plant or section.

Even though the release may not have ignited, the Fire Service should be asked to attend site and stand-by.

If ignition of the release occurs, the aim is to control the fire by isolating the supply to the affected plant or section, rather than by extinguishing it using fire-fighting methods. If nearby equipment is at risk from thermal radiation then cooling water is applied by the Fire Service.

8.1 Release of Natural Gas from Cavities

The Safety Report for the <<Location>> site derived a complete range of release scenarios from small scale reasonably foreseeable releases up to low probability large scale events.

The worst incident that can be foreseen on this site is <<Incident information>>. Both of these potential incidents are considered in further detail in the following sections, to cover the required emergency response to the full range of events considered in the Safety Report.

<<Further incident information>>

<<Information regarding the required incident response>>

9. SITE ISOLATION

<<Site isolation details>>

10. ENVIRONMENTAL IMPACT

10.1 Environment Emergency Response Plan (EERP)

All <<COMAH Operator>> COMAH and NIHHS storage sites have a site specific Environment Emergency Response Plan (EERP) located on site which should be referred to in the event of an incident. The EERP document:

- Describes the site, identifies potential environmental hazards and describes the key environmental legislation applicable to the site.
- Categorises possible environmental incidents and the potential severity of these incidents.
- Gives guidance on the action to be taken in the event of an incident
- Provides details of notification, clean up and reporting requirements as well as relevant contact details.

10.2 Site History

<<site history details>>

10.3 Local Environment

This section includes a description of the environment surrounding the site. This is to establish the context of the site within the local environment and to identify any significant areas that could be affected by a major accident at the site. <<site information>>

The Department of Environment, Transport and Regions (DETR), now the Department of Environment, Food and Rural Affairs (DEFRA), published a report ‘Guidance on the Interpretation of Major Accident to the Environment for the Purposes of the COMAH Regulations’. This lists environmental receptors that should be considered when investigating the potential effects of a major accident, and includes definitions of thresholds above which a Major Accident to the Environment (MATTE) is deemed to have occurred. Any of the environmental receptors listed in the DEFRA publication that are present in the area surrounding the <<Location>> site are described below.

Geographical Location

<site location details>>

Infrastructure

<site location details>>

Surrounding Populations

<site location details>>

Meteorology

<site location details>>

Geology and Hydrogeology

<site location details>>

Site Drainage

<site location details>>

10.4 Environmentally Significant Sites and Species

Sites within the maximum hazard range

Statutory designated sites

<site location details>>

Other Sites

County Wildlife Site

<site location details>>

Scarce Habitats

The DEFRA guidance classes scarce habitat as any Biodiversity Action Plan habitats. In the UK Biodiversity Action Plan (UKBAP), habitats can be classed as either ‘Broad Habitat’ or ‘Priority Habitat’. ‘Broad Habitats’ are those habitats for which the current issues affecting the habitat have been assessed and broad policies to address these issues have been drawn up. ‘Priority Habitats’ are less widespread than ‘Broad Habitats’ and have more detailed actions and targets for conserving them.

Coastal Floodplain Grazing Marsh, which is a UKBAP Priority Habitat, surrounds the site. It is described as “periodically inundated pasture or meadow, with ditches that maintain the water levels, containing brackish or fresh water. The ditches are especially rich in plants and invertebrates. Almost all areas are grazed.”

Sites beyond the maximum hazard range

There are some designated sites, beyond the maximum hazard range but within the vicinity of the <<Location>> Storage site. Whilst these cannot be affected by an incident on the site as they are beyond the maximum hazard range, the sites will be briefly described to give an indication of the environmental quality of the area around the site, and also because they contain mobile species which could be present at the site.

<site location details>>

10.5 Recreation

There are no important recreational sites within the maximum hazard ranges.

10.6 Historic Buildings, Archaeological and Geological Sites

There are no listed buildings, scheduled ancient monuments or areas of historic or archaeological or geological interest within the maximum hazard ranges surrounding the <<Location>> Installation.

11. TASK CARDS

In order to ensure a consistent and comprehensive response to a major incident on an NGN gasholder site, a series of Task Cards are provided that define the duties and responsibilities of the Incident Controller and Site Incident Controller.

11.1 Task Card - Incident Controller

The Incident Controller has overall responsibility for directing operations throughout an emergency.

The responsibilities of the Incident Controller include:

1. Advising the Head of Operations/Network or their nominated deputy of any incident or emergency that required the site Emergency Plan to be initiated. Outside normal working hours the initial contact with Network would be through the Network level 4 standby.

2. Attending either the Network Incident Room, or the scene of the incident, and assuming responsibility for overall control of the incident from the Site Incident Controller.

3. Confirming that in the event of an emergency the Emergency Services have been summoned, that <<COLLABORATING AGENCY>> have been informed and the <<Local Authority>> Emergency Planning Unit has been notified.

4. Depending upon circumstances, ensuring that appropriate Network operational personnel are mobilised, together with any other resources they think are necessary.

5. Reviewing and assessing developments, as appropriate, to help predict the most likely course of an emergency.

6. Directing the shutting down of system valves and evacuation of buildings, as appropriate, in consultation with the Site Incident Controller and Emergency Services.

7. Ensuring that casualties are receiving adequate attention and, if appropriate, arranging for additional assistance. They should also ensure, in liaison with the police, that relatives are kept informed of missing or injured people.

8. Ensuring that all personnel under their control are accounted for.

9. Arranging for an ongoing record to be kept of the emergency and any actions undertaken to mitigate its effects so as to provide supporting evidence of the decisions made.

10. Providing for the welfare needs of establishment personnel, for example the provision of food and drinks, relief and the means to keep relatives informed.

11. Depending on the nature of the incident, it may be necessary to set up the Network control room to support and/or co-ordinate the overall emergency response (e.g. Network Planning, off-site response).

12. Making initial contact with the Network Communications Department who will establish links with news media and issue information and statements, as appropriate, in liaison with the Emergency Services. For contact with the HSE, implement the Network Procedure following consultation with the Health & Safety Section.

13. The Incident Controller together with the Communications Department is responsible for all off-site communications and as such the Incident Controller should ensure that adequate resources are available in the Emergency Control Room to carry out this task.

14. Reviewing and assessing the incident at appropriate intervals and updating the Emergency Room Staff and Emergency Services Liaison Officers of all significant developments.

15. Ensuring that full consideration is given to the preservation of evidence.

16. Controlling the rehabilitation of affected areas after the emergency.

17. Declaring the emergency over when appropriate.

18. Ensuring the incident is debriefed and lessons learned are recorded and acted upon.

19. Assessing the emergency and as soon as practical providing information to Network who will arrange for any RIDDOR reporting that may be required.

The incident may also be reportable under COMAH, which must be clearly stated on the RIDDOR report. Guidance on the reporting of major accidents under COMAH is given in NGN COMAH 6.

11.2 Task Card - Site Incident Controller

The function of the Site Incident Controller is to make safe and direct all operations in the event of an incident or emergency on the site. The Site Incident Controller reports to the Incident Controller.

The responsibilities of the Site Incident Controller include:

1. Immediate assessment to determine if the incident is, or may develop into, a major emergency. If so, the site Emergency Plan should be activated. If appropriate the Off-Site Emergency Plan will be activated by the <<Local Authority>> Emergency Planning Officer.

2. Assuming the responsibilities of the Incident Controller until the latter is in place.

3. Giving consideration to the safety of the public and personnel carrying out emergency operations at all times.

4. Ensuring that the Emergency Services are alerted.

5. Alerting the Local Authority Emergency Planning Officer (EPO).

6. Informing the Network Operations Director (NGN) is informed.

7. Ensuring that the <<COLLABORATING AGENCY>> Control Centre is informed

8. Ensuring that the Head of Operations/Network is alerted and the incident is reported to the Emergency Call Centre (if the report did not originate there), and instruct the Call Centre to inform the Network Management.

9. Control of rescue and fire fighting operations until the arrival of the Emergency Services when control will normally be passed over to a Senior Fire Officer.

10. Working with the Fire Service in the search for casualties and evacuation of non-essential workers to a safe distance. (Refer to hazard distances in Section 5).

11. Setting up a communication point at a suitable location close to the site.

12. Giving advice and information, as requested, to the Emergency Services at the scene (primarily the Fire Service).

13. Briefing the Incident Controller and keeping the Network Incident Room informed of all significant developments. This may require the appointment of an assistant to the Site Incident Controller from site personnel to deal with communication links.

12. TRAINING AND TESTING REQUIREMENTS

Relevant Network personnel are briefed about actions to take in the event of a major emergency.

Regular exercises are carried out to familiarise personnel with emergency procedures.

Emergency procedure training is provided for all those who may be involved to ensure that they are aware of their roles and responsibilities.

The Safety and Technical Competencies framework covers competency in an emergency role.

The procedure for the maintenance and testing of this Emergency Plan is in accordance with Northern Gas Networks Procedure for the Preparation, Maintenance and Testing of Emergency Plans (NGN/PM/COMAH/5).

The maximum recommended intervals for Emergency Plan testing for COMAH “Top Tier” sites is an annual desktop exercise and an on-site exercise every 3 years.

APPENDIX A: SITE LAYOUT AND ISOLATION DIAGRAM

<<Site Layout Diagram>>

<<Isolation Diagram>>

APPENDIX B: CALL-OUT DETAILS

AUTHORISED PERSONS, INTERNAL CONTACTS, EXTERNAL CONTACTS

Personnel Authorised to Instigate Emergency Procedures

Normal Working Hours

- Head of E&I & Maintenance
- Maintenance Operations Manager - Deputises for Head of E&I & Maintenance

Outside normal working hours (Standby Rota)

- Head of E&I & Maintenance
- Maintenance Operations Manager
- Area Operations Manager
- Network Officer

Internal Contacts

Location	Contact Details
<<Address details>>	<<Telephone Number>>

Network Personnel

Designation	Name	Work Number	Mobile Number
Head of E&I & Maintenance	<<contact name>>	<<Telephone Number>>	<<Telephone Number>>
Maintenance Operations Manager	<<contact name>>	<<Telephone Number>>	<<Telephone Number>>
Area Operations Manager	<<contact name>>	<<Telephone Number>>	<<Telephone Number>>
Network Officer	<<contact name>>	<<Telephone Number>>	<<Telephone Number>>
Network Officer	<<contact name>>	<<Telephone Number>>	<<Telephone Number>>
Network Officer	<<contact name>>	<<Telephone Number>>	<<Telephone Number>>

External Contacts

Emergency Services (First Call)	Address (Secondary Contact)	Contact Details
POLICE (first call) **999**	<<Contact address>>	<<Telephone Number>>
FIRE (first call) **999**	<<Contact address>>	<<Telephone Number>>
AMBULANCE (first call) **999**	<<Contact address>>	<<Telephone Number>>

Enforcing Authority	Address	Contact Details
HSE	<<Contact name and address>> Out of Office Hours Duty Officer	<<Telephone Number>>
Environment Agency	Contact with the EA must be made by Environmental Team – see Environmental Emergency Response Plan for contact details. EA Incident Hotline EA Enquiries	<<Telephone Number>>
Emergency Planning Unit	<<Local Authority>> Emergency Planning Unit (Office Hours) Out of Hours Duty Officer	<<Telephone Number>>

Utilities	Address	Contact Details
Power	<<organisation name>>	<<Telephone Number>>
Water	<<organisation name>>	<<Telephone Number>>

Site Neighbours

Site Neighbours within Public Information Zone	Address	Contact Details
<<organisation name>>	<<Contact address>>	<<Telephone Number>>
<<organisation name>>	<<Contact address>>	<<Telephone Number>>
<<organisation name>>	<<Contact address>>	<<Telephone Number>>
<<organisation name>>	<<Contact address>>	<<Telephone Number>>
<<organisation name>>	<<Contact address>>	<<Telephone Number>>
<<organisation name>>	<<Contact address>>	<<Telephone Number>>

Additional External Contacts	Address	Telephone
Railway Operator	Control Duty Manager	<<Telephone Number>>
Port Operations Centre	Harbour Master’s Office	<<Telephone Number>>

APPENDIX C: EMERGENCY RESPONSE ORGANISATION

Figure 3.1 - INITIAL ACTIONS EMERGENCY RESPONSE

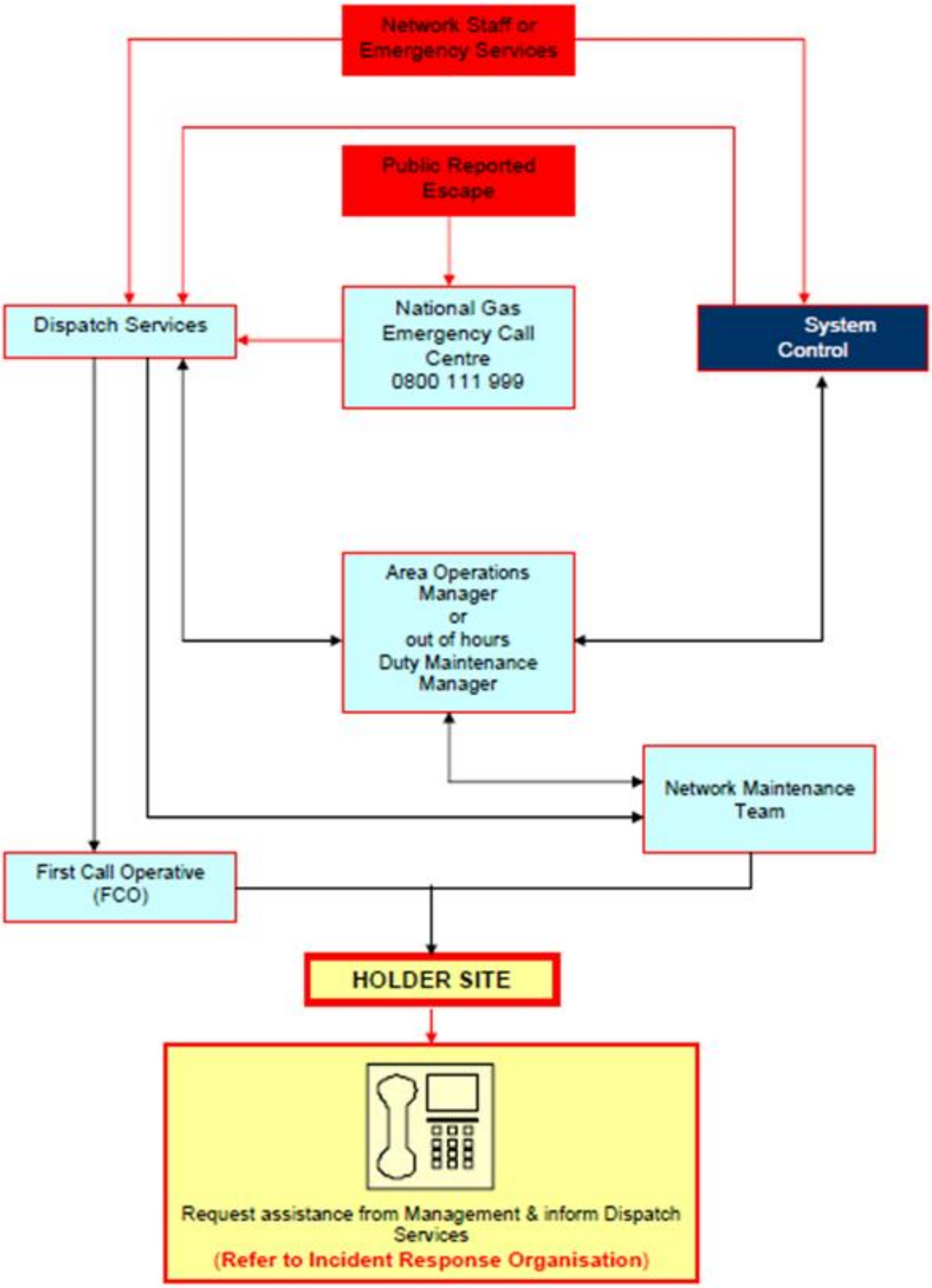
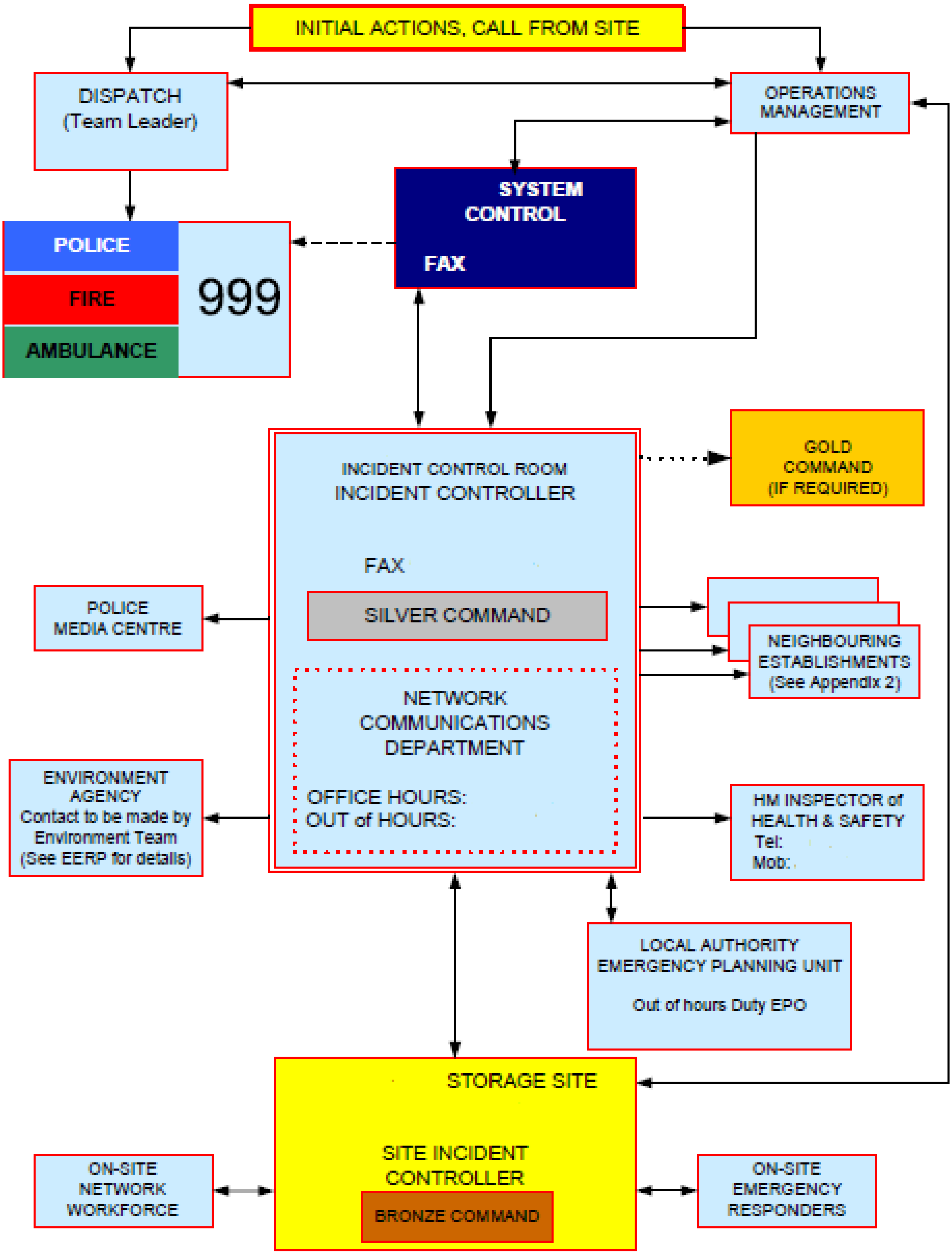
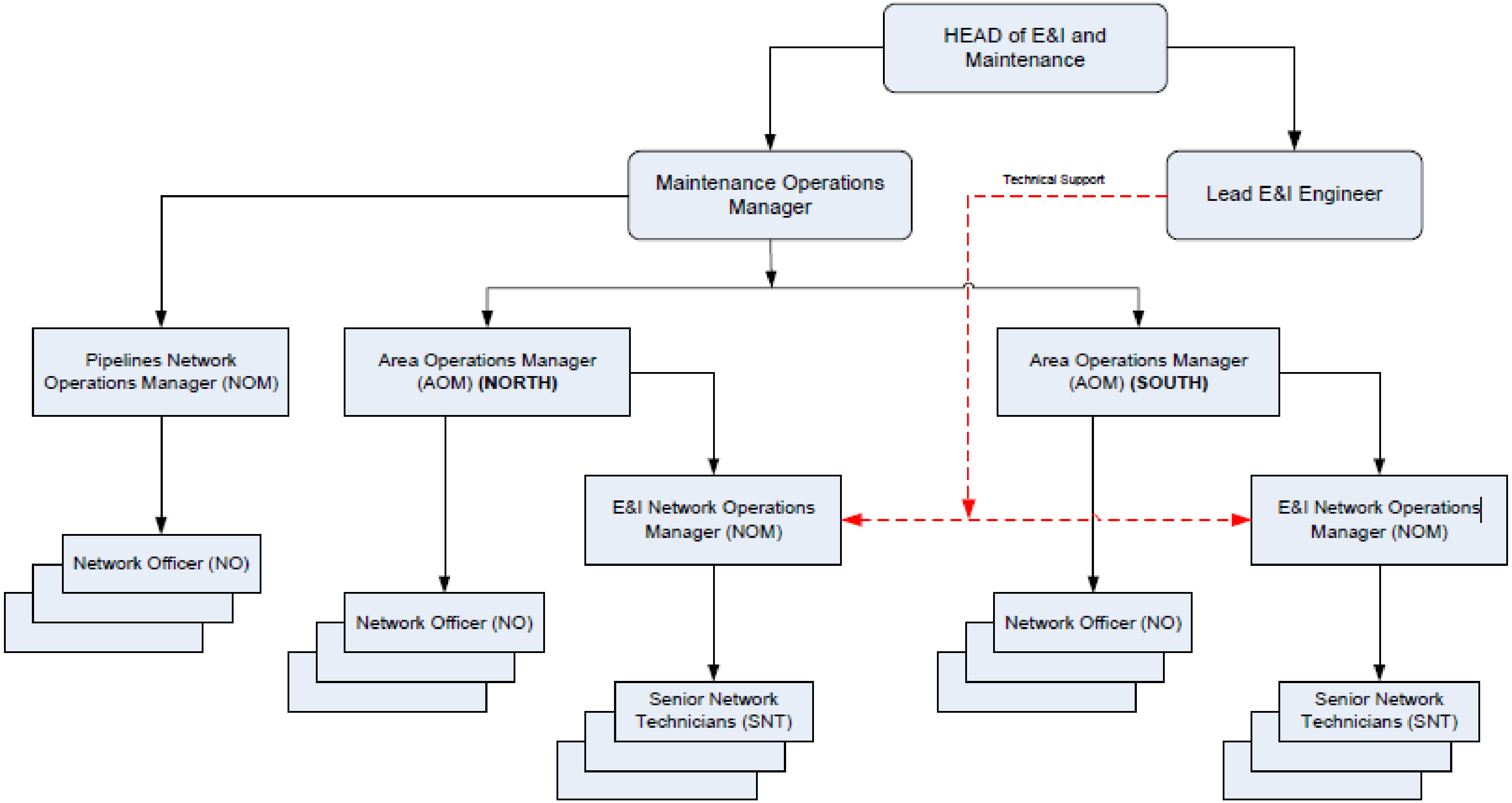


Figure 3.2 - INCIDENT RESPONSE ORGANISATION



APPENDIX D: MAINTENANCE AND E&I STRUCTURE



APPENDIX E: HAZARD DISTANCES

Large Hole (25mm) in Wellhead

<<Potential impact details>>

Failure of Wellhead (Horizontal Release)

<<Potential impact details>>

APPENDIX F: SITE ISOLATION VALVES

<<Isolation valve diagram>>

<<Isolation valve details>>

APPENDIX G: TECHNICAL DETAILS OF EQUIPMENT ON SITE

<<Technical details>>

APPENDIX H: ENVIRONMENTAL PLAN

<<Environmental plan diagram>>

APPENDIX I: ALARM ALERT PROCEDURE

STORAGE SITES

ALARM ALERT FOR PRS SITE & WELLHEADS

REMEMBER

- log on at Control Centre before

IMPORTANT: Split Teams (e.g. working at Wellheads and PRS on same visit) MUST be in RADIO CONTACT at all times

ALARM SOUNDS

IF A WARNING SIREN WHICH INDICATES A FIRE OR TOXIC RELEASE IS HEARD ON SITE
(Note: Alarm tests are 10.00am each Wednesday)

↓

TAKE FOLLOWING ACTION

- RADIO CONTROL CENTRE FOR INSTRUCTIONS
- INFORM ALL SITE PERSONNEL OF EMERGENCY
- IF IN PRS SITE CONTROL ROOM AWAY FROM RADIO CONTACT RING FOR INSTRUCTIONS
- IF SITE EVACUATION IS REQUIRED PROCEED AS INSTRUCTED
- PREVENT FURTHER SITE ACCESS – INFORM LINE MANAGER

↓

ALL CLEAR

INFORM LINE MANAGER

APPENDIX J: <<COLLABORATING AGENCY>> PROCEDURE CFS-018

<<Procedure details>>

Appendix 4: Sample Mock Up Image from Tabletop Role Play Exercise

The following image is taken from the exercise material that was used in Exercise Dragon which is discussed in Chapter 6 Section 6.1.3. The image was used to set the scene of the incident within the exercise.

Appendix 5: The Prototype Development Methodology

This appendix details the software methodology approach adopted to develop the virtual simulation prototype used within this study. A process was required that allowed the researcher to design and develop the software, in collaboration with NGN emergency response strategy experts. Software methodologies describe the approach to designing and building software. Tools and techniques are supplied within a software methodology to support each phase of the software development process. A software methodology was required that allowed the researcher to convey design requirements to emergency response strategy experts, that may have little or no technical knowledge of software systems. The software methodology used to facilitate the development of the prototype is described.

The Unified Modelling Language and the Unified Process

The Unified Modelling Language (UML) is a visual modelling language that can be used to describe software design requirements to users with no prior technical knowledge (Larman, 2005; Arlow and Neustadt, 2005; Schach, 2004; IBM, 1998). Created by Booch, Jacobson and Rumbaugh (1999) and managed by the Object Management Group (OMG) (2010), UML is the international, industry standard notation for representing Object-Oriented (OO) systems (Schach, 2004; IBM, 1998). The Unified Process (UP) is an iterative and incremental software methodology that uses the UML to develop OO systems (Arlow and Neustadt, 2005; IBM, 1998).

There are five workflow stages to the UP:

1. The requirements workflow
2. The analysis workflow
3. The design workflow
4. The implementation workflow
5. The test workflow

Each workflow stage is performed iteratively and incrementally. Requirements and analysis workflows tend to have more emphasis at the beginning of a project, with implementation and testing having more at the end. The UML provides diagrams to model the structure and behaviour of the software throughout each workflow stage. The structure diagrams model the static structure of the system and the behaviour diagrams model the dynamic behaviour of the system. The UP is described in further detail along with the UML techniques used for the development of the software simulation prototype.

The Requirements Workflow

The requirements phase of software development is concerned with understanding what the system should do (Arlow and Neustadt, 2005). Systems Analysts draw on the knowledge of system experts to understand the system. The term system expert is used here to describe a person who has expert knowledge about the system to be developed and its processes. System experts don't have to be technically minded to be considered an expert. Having knowledge of a process or requirement of the system is equally as important as being able to build the system (Shneiderman and Plaisant, 2005). A software developer may not necessarily be a system expert and may have little or no experience of the requirements of a system, relying on system experts to provide this information. Personnel from NGN and participants from the emergency response planning exercises that have knowledge of developing and participating in emergency response planning exercises, are considered system experts of the software simulation prototype developed for this research. The researcher assumes the role of the software designer, analysis and developer liaising with system experts to capture and model requirements for the design and development of the system.

Use case diagrams are a notation provided within the UML for capturing requirements. Use cases define system boundaries and describe what the system does, rather than how it does it or what it looks like (Arlow and Neustadt, 2005). Use cases describe the interface between the system and its users, as well as any interfaces with other systems. A use case diagram provides a visual notation that demonstrates the interactions and sequence of activities a task requires. Created in collaboration between the software analyst and the system expert, each use case diagram models one system activity at a time (Arlow and Neustadt, 2005). These use cases make up the key requirements of the system and because they are developed independently of each activity, they can be altered at any time during the software development lifecycle.

The Analysis Workflow

The analysis workflow seeks to provide a more detailed understanding of the requirements to the software developer (Schach, 2004). The detail of the designs developed at the analysis stage are not necessarily relevant to the client or system expert’s understanding of the system and are therefore modelled as a separate process (Schach, 2004).The analysis stage of the prototype development was completed by the researcher.

Use case specifications provide a more detailed textual description of use case diagrams (Booch et al., 1999). Use case specifications can be used to specify pre and post conditions for an activity, the main flow of events and any alternative paths. Objects and interactions contained within the use cases were identified during the analysis stage of this project and used to inform the design of the structural and behavioural diagrams required to build the system.

The Design Workflow

The design stage refines the information captured in the analysis stage and models it in such a way that it can be implemented (Schach, 2004). The structure of the system and its interactions therein are designed during this phase. The aesthetic design of the Graphical User Interface (GUI) may be agreed during the design process. The design phase also involves selecting the programming language to develop the software (Schach, 2004). The software simulation platforms and technologies to be implemented may also be considered during the design phase.

Structural Design

The design of the structure of the system is concerned with modelling the data and processes of a system (Arlow and Neustadt, 2005). The objects and operations identified in the analysis phase may be designed and modelled in more detail during this stage. The OO paradigm relies on the concept of using methods to develop objects that model the data and processes (Arlow and Neustadt, 2005). An object is the thing that allows users to perform tasks within a system. Objects have properties, behaviours and relation to other objects. For example, an online library system may contain details of library members and the books they currently have on loan. A user may log into their account and view details about the books they are borrowing. A system such as this would require the user, the books and the library account to be modelled as objects, containing their own attributes and behaviours and interacting with other objects within the system.

Class diagrams are a structural diagram provided within the UML to model objects within a system and the interactions between them. Objects identified within use cases are abstracted and modelled into the class diagrams. Class diagrams describe an object's attributes and methods and the relationships they have with other objects. Two types of classes can be modelled: an entity class and a boundary class. The entity class models the structure of the objects within the system. The boundary class models the input and output interfaces of the system and the user. Input screens, output screens and printed reports are all modelled within boundary classes.

Designing the GUI

The GUI acts as the window between the user and the software. The UML provides diagrams for designing the structure and behaviour of the system, but not for modelling the GUI. Boundary class diagrams inform the GUI design by defining the user input and output interfaces, but do not specify aesthetic look and feel of the design. The aesthetic design is concerned with developing the look and feel of the system. Guidelines exist that describe standard techniques that can be used to enhance the user experience. Such techniques include representing elements with the use of metaphors, using specific font types, defining the colour and contrast of an interface and the layout of elements on a screen (Microsoft , 2012; W3c, 2012; Shneiderman and Plaisant, 2005; Nielson, 1993).

Five steps for designing the GUI are proposed:

1. Identify the elements of the user interface. Many of the elements will be defined within the boundary classes. Subsequent elements such as visual cues or specific graphical features like a logo may be defined as a separate process.
2. Develop a preliminary design that lays out the elements of the screen. Use lo-fidelity prototyping techniques to test different layout designs.
3. Test preliminary designs to ensure they meet the requirements of the system specified in the use case diagrams. Develop a high-fidelity prototype further on the design process.
4. Design and test the aesthetic components of the GUI such as colour and fonts with system experts.

Developing software prototypes and the terms hi-fidelity and lo-fidelity prototypes are discussed further.

Developing a Prototype

Prototyping is a technique used to test designs before software is fully developed. In the early design stages, prototyping can be used to test out requirements and interface designs with users or stakeholders of a system (Rettig, 1994). Low cost, lo-fidelity paper prototyping is a method commonly used for testing out designs with users at an early stage (Rick et al., 2010; Rettig, 1994). Software prototypes offer a hi-fidelity approach to evaluating and testing software without the system being complete (Bowman et al., 2005).

With lo-fidelity paper prototypes, interfaces are sketched by hand and amended using pens, paper, tabbed indexed cards and Post-it notes. Paper prototypes model the system and its processes rather than detailed graphic designs (Rettig, 1994). Test scenarios are developed to represent typical activities to be performed within the system. The user is asked to perform tasks set out within the scenario using the prototype (Rudd et al., 1996; Rettig, 1994). The designer acts as the computer and simulates the computer response by alternating screen drawings or overlaying drawings with Post-its or other materials (Rettig, 1994).

Designs can be thrown away and redrawn at a relatively low cost in comparison to digital formats, making paper prototypes a flexible and speedy technique for testing out alternative designs (Sefelin et al., 2003; Rettig, 1994). Content, layout, structure, input and output techniques can all be tested using paper prototypes, detailed design such as colour combinations, font styles and button sizes should be tested using software prototypes (Rudd et al., 1996; Rettig, 1994).

Hi-fidelity prototypes respond to commands and represent the core functionality of the system, without it being finalised (Rudd et al., 1996). More expensive than paper prototypes in terms of technology and development costs, high-fidelity prototypes are more suited to being used later on in the software development lifecycle (Rudd et al., 1996, Rettig, 1994). The Wizard of OZ (WOZ) approach is a technique used for software prototypes, whereby the system appears to be fully functional, though only some of its elements work (Martin and Hanington, 2012; Bowman et al., 2005). The WOZ method is a flexible, iterative approach, Martin and Hanington (2012, p.204) recommend using the WOZ approach to guide the ‘exploratory’ and ‘conceptual’ design phases of a project.

Unlike paper prototypes that require a designer or facilitator to act as the computer, high-fidelity prototypes allow users to interact with the software and test out navigational structures and responses (Rudd et al., 1996). Users can test out the software and get a “feel for how the product will operate” allowing users to “make informed recommendations about how to improve its user interface”, (Rudd et al., 1996, p.81). A software prototype can be developed to include new functionality or features with each iteration.

Wireframing is a technique used to demonstrate how elements are to be laid out on screens and show information flows. At this stage no branding or high end graphical elements are shown, the wireframe is simply a template to discuss information flows. Wireframes can be as simple as a PowerPoint presentation that mimics navigation back and forth throughout the system. Wireframing is a technique used to develop high-fidelity prototypes.

Identifying the Software Platform and Technology

The technology used to implement the design is identified during the design phase. Research of existing applications that perform similar activities can be undertaken to understand the technical abilities different technologies provide. Technological requirements may be imposed by the end user environment. Part of the requirements capture process serves to understand any technical boundaries the user’s environment poses.

The Implementation and Testing Workflows

The final stages to the software development process concern implementing and testing the design. The implementation stage involves developing the system from the design. The purpose of software testing is twofold: to test that the software is able to perform the functions required of it and to test the software is able to be used (Bowman et al., 2005; Schach, 2004). Testing can happen both during the development process and when the software is at a more complete stage in the development lifecycle (Schach, 2004). Four phases of testing are recommended by Schach (2004), unit, integration, product and acceptance testing. Unit testing occurs as each component is developed, upon successful completion of the unit testing phase, the components are then integrated together and tested for integration testing. When the software is complete it is tested as a whole product.

The unit, integration and product testing phases test the system against the requirements and design models, performance testing can also be completed at this stage. These phases are conducted iteratively and incrementally as a continuous process, until the prototype is ready for evaluation by users. As components of the prototype are developed they are tested against use cases to assess their completeness. After requirements' testing is complete, the prototype should be tested and evaluated by the system experts for acceptance. During acceptance testing, the software is shown to the client or user and they test the system to make sure they are satisfied with the overall system.

The limitations imposed on the PhD research mean that a software simulation prototype rather than a fully functional system has been developed for the study. As such, the prototype was subjected to several phases of acceptance testing with system experts to ensure the prototype satisfied the requirements needed to perform the comparative evaluation of the virtual simulation prototype against the current tabletop role play method for testing emergency response strategies. The development of the virtual simulation prototype is described in Chapter 7.

Appendix 6: Emergency Software Simulation Prototype Design Documentation

This appendix presents the design documentation foe the software simulation prototype. The system requirements are documented along with the design of the database and business layer classes. The process of developing the requirements can be found in Chapter 6 Sections 6.1.4-6.2 along with a more detailed description of what the requirements mean..

System Requirements

Table 30 Prototype Requirements

Number	Requirement
1	Add an organisation and role to the system
2	Perform an exercise
3	Retrieve exercise information

Table 31 Prototype Requirements

Number	Requirement
1	Add an organisation and role to the system
2	Perform an exercise
3	Retrieve exercise information
4	Secure log in with authentication

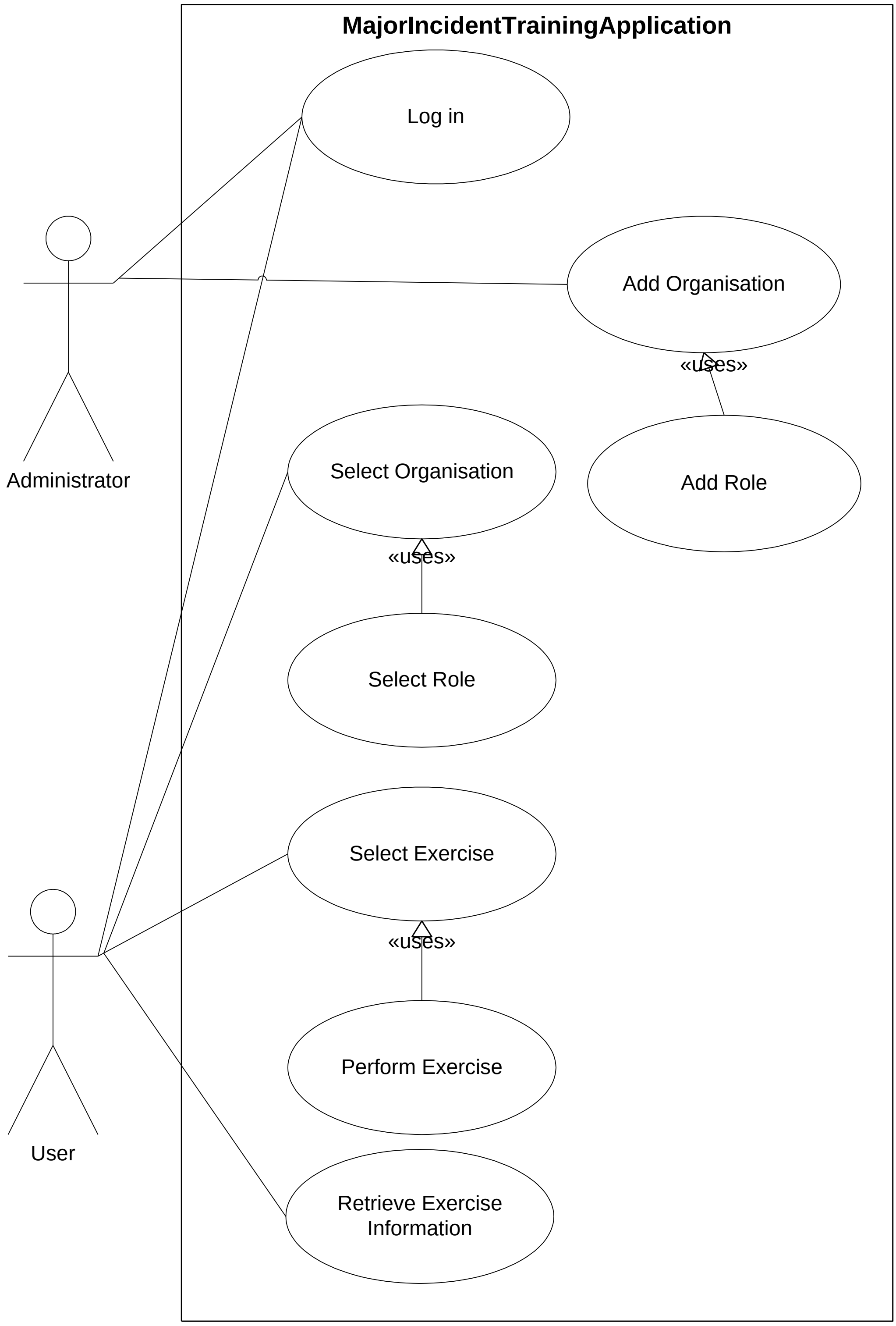
Table 32 Prototype Requirements

Number	Requirement
1	Add an organisation and role to the system
2	Perform an exercise
3	Retrieve exercise information
4	Secure log in with authentication
5	Communicate with other users

Table 33 Prototype Requirements

Number	Requirement
1	Add an organisation and role to the system
2	Perform an exercise
3	Retrieve exercise information
4	Secure log in with authentication
5	Communicate with other users
6	The ability to use auditory and visual cues should be provided
7	The system should provide an element of urgency

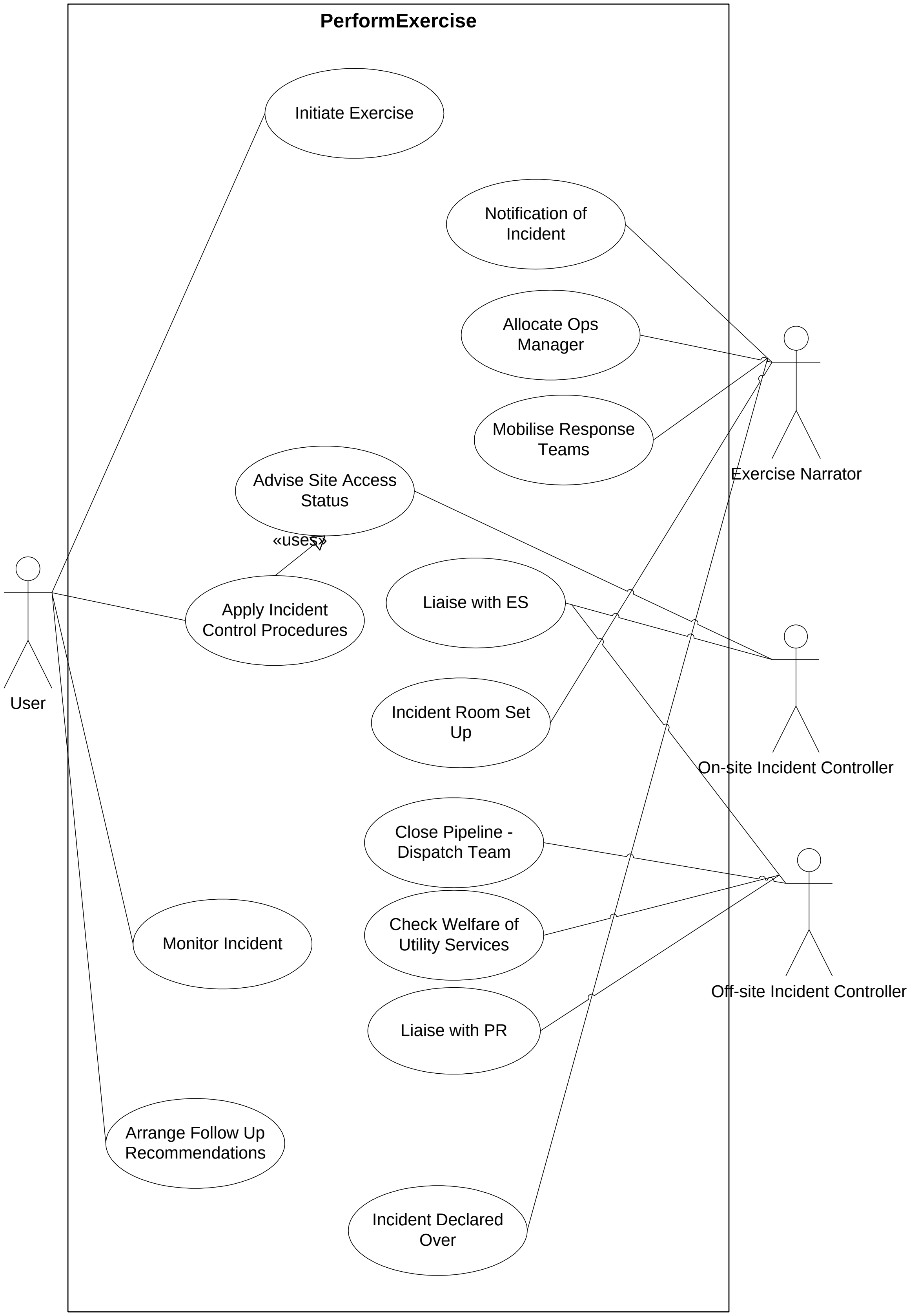
Use Case 1 – Major Incident Management Training Application



Use Case 1 Specification

Name:	MajorIncidentManagementTrainingApplication
ID	UC1
Brief Description	An Administrator will have the ability to add and remove organisations and roles. A User can select an exercise, participate in performing an exercise and retrieve exercise information. An Administrator will be able to perform all the actions that a User can perform.
Primary Actors	Administrator; User
Secondary Actors	None
Preconditions	None
Postconditions	None
Main Flow	1. Log in with user name and password 2. Administrator adds organisations and roles to the system. 3. Administrator or User selects a role from an organisation. 4. User chooses an exercise to complete. 5. User performs exercise. 6. User retrieves feedback from a completed exercise.
Alternative Paths	Display message if invalid user name or password entered

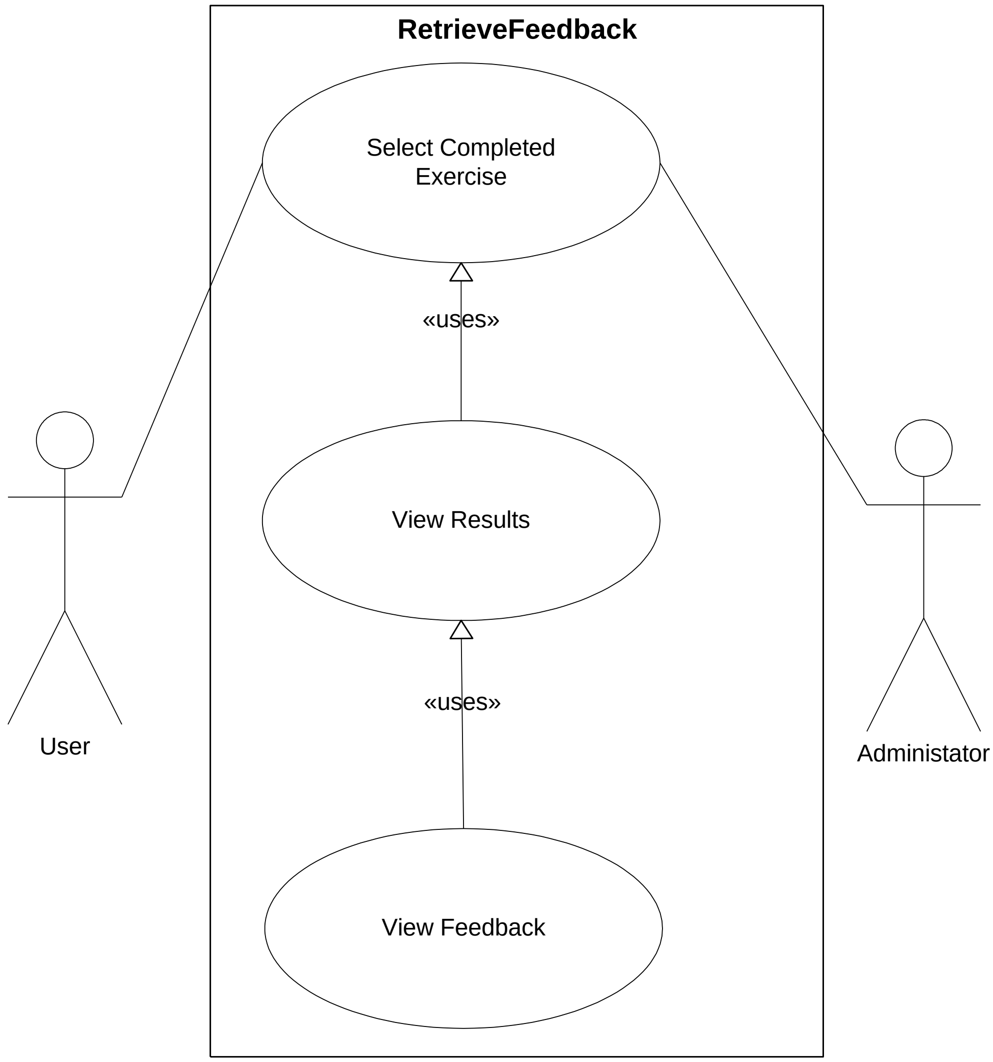
Use Case 2 – Perform Exercise



Use Case 2 Specification

Name:	PerformExercise
ID	UC2
Brief Description	A User begins the exercise. Users submit responses to the exercise. Users request resources from Administrator. The Administrator releases resources.
Primary Actors	User
Secondary Actors	Exercise Narrator; On-Site Incident Controller; Off-Site Incident Controller An Exercise Narrator refers to the part of the system that relates the story or details of the exercise to the User. For the purpose of this Use Case both the On-Site Incident Controller and Off-Site Incident Controller refer to an automated role within the system.
Preconditions	User must be logged in to use system
Postconditions	None
Main Flow	1. User selects an exercise. 2. Exercise Narrator notifies the User of the incident. 3. Exercise Narrator allocates an On-Site Incident Controller. 4. Exercise Narrator mobilises the response teams. 5. On-Site Incident Controller advises the User of the site access status, i.e. on-site access available or not. 6. User applies the incident control procedures. 7. On-Site Incident Controller liaises with the emergency services. 8. Exercise Narrator advises that the incident room has now been set up. 9. Off-Site Incident Controller makes recommendations about whether or not to close the pipeline and dispatches the utility services to carry these recommendations out. 10. Off-Site Incident Controller checks the welfare of the utility services. 11. Off-Site Incident Controller liaises with the PR team. 12. User monitors the incident. 13. User makes follow up recommendations. 14. On-Site Incident Controller declares the incident over.
Alternative Paths	Message requesting user to log in with correct name and password

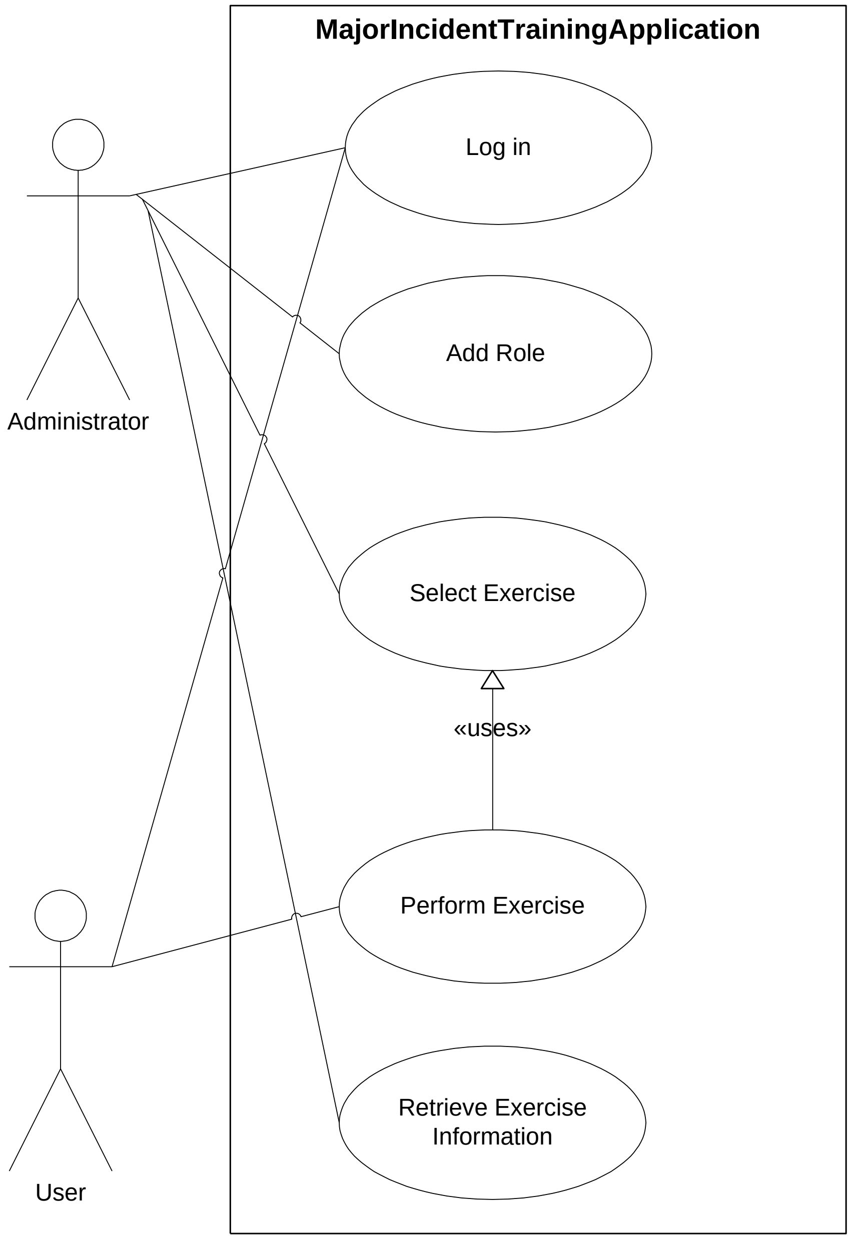
Use Case 3 – Retrieve Feedback



Use Case 3 Specification

Name:	RetrieveFeedback
ID	UC3
Brief Description	This Use Case describes the process of retrieving the results from a completed exercise and the feedback that shows whether a task was completed as expected or not.
Primary Actors	Administrator, User
Secondary Actors	None
Preconditions	Exercise must be completed and results recorded
Postconditions	None
Main Flow	1. User selects an exercise to retrieve the results from. 2. User views results for the exercise. 3. User chooses to view the feedback from the exercise. The feedback will provide a visual report or summary of the route taken to complete the task. Where an exercise is incomplete or not conducted as required according to the exercise plan, feedback will be provided on how to complete the exercise successfully.
Alternative Paths	None

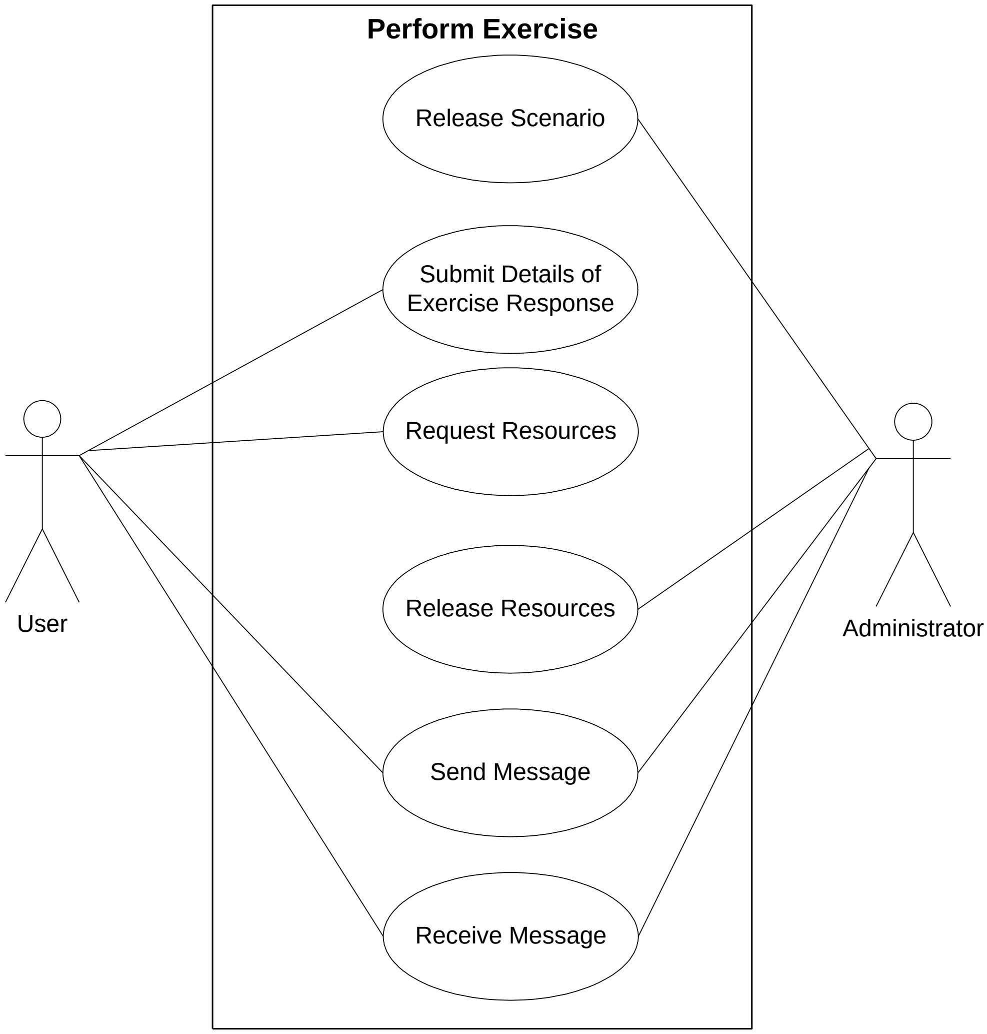
Use Case 1.1 – Major Incident Management Training Application



Use Case 1.1 Specification

Name:	MajorIncidentManagementTrainingApplication
ID	UC1
Brief Description	The system can be accessed via a secure log in. The Administrator will have the ability to add and remove roles. Each user logs into the system, when all users are logged into the system the Administrator will begin an exercise. The users and administrator collaborate within the system to perform the exercise. Once an exercise is complete the Administrator can retrieve details of the exercise.
Primary Actors	Administrator; User
Secondary Actors	None
Preconditions	None
Postconditions	None
Main Flow	1. Log in with user name and password 2. Administrator adds roles to the system. 3. Administrator chooses an exercise. 4. User and Administrator perform the exercise. 5. Administrator retrieves feedback from a completed exercise.
Alternative Paths	Display message if invalid user name or password entered.

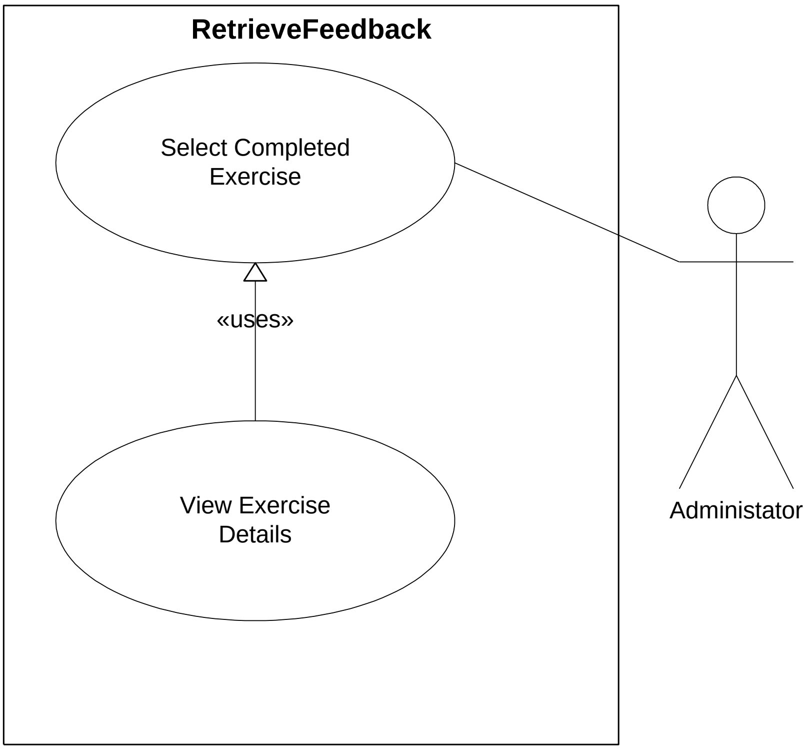
Use Case 2.1 – Perform Exercise



Use Case 2.1 Specification

Name:	PerformExercise
ID	UC2
Brief Description	An Administrator begins the exercise. Users submit responses to the exercise. Users request resources from Administrator. The Administrator releases resources. User/Administrator submits message, User/Administrator receives message.
Primary Actors	Administrator, User
Secondary Actors	None
Preconditions	1. User must be logged in to use system 2. An exercise must be initiated before users can submit responses to an exercise or request resources.
Postconditions	None
Main Flow	1. Administrator selects an exercise. 2. User submits details of incident response or requests further information. 3. Administrator releases resources upon request. 4. User sends message. 5. User receives message.
Alternative Paths	None

Use Case 3.1 – Retrieve Feedback



Use Case 3.1 Specification

Name:	RetrieveFeedback
ID	UC3
Brief Description	The Administrator retrieves the results of a completed exercise.
Primary Actors	Administrator
Secondary Actors	None
Preconditions	Exercise must be completed and results recorded
Postconditions	None
Main Flow	1. Administrator selects an exercise to retrieve the results from. 2. Administrator views results for the exercise.
Alternative Paths	None

Database Design

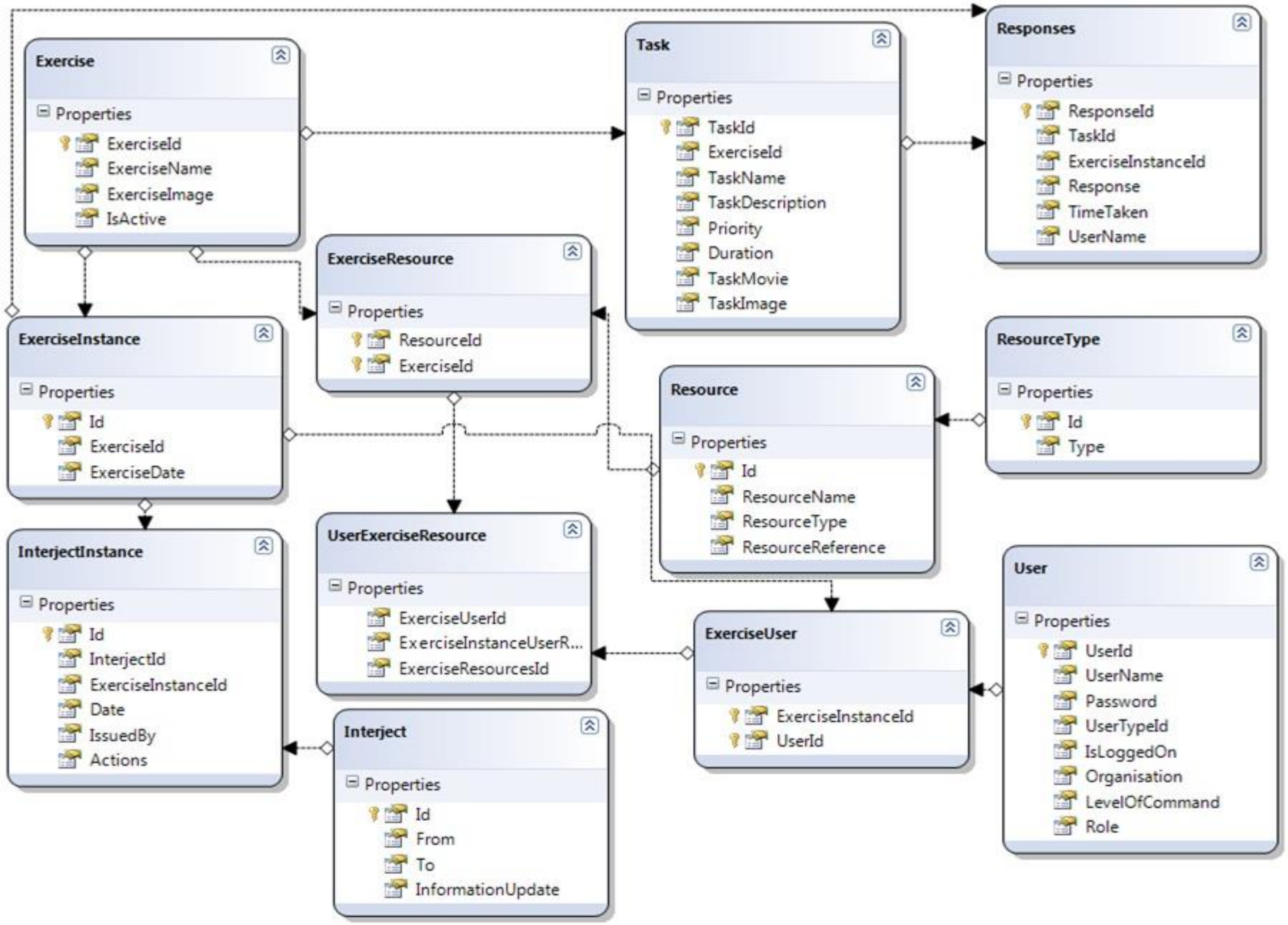


Figure 26 The Data Structure

Business Logic

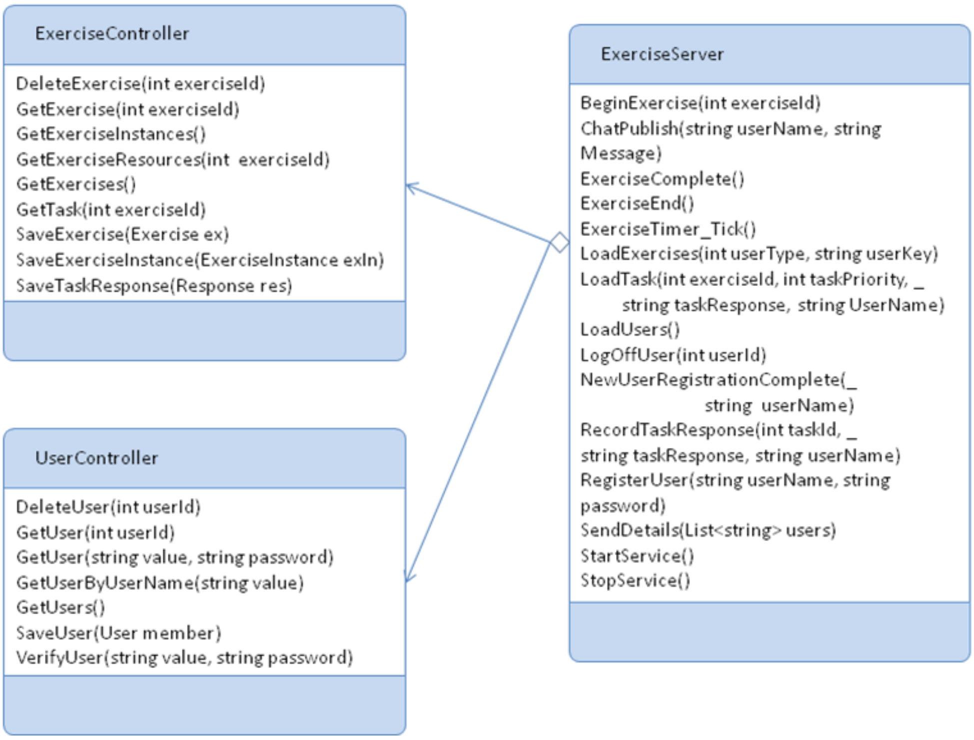


Figure 27 Business Classes

Presentation Layer Classes

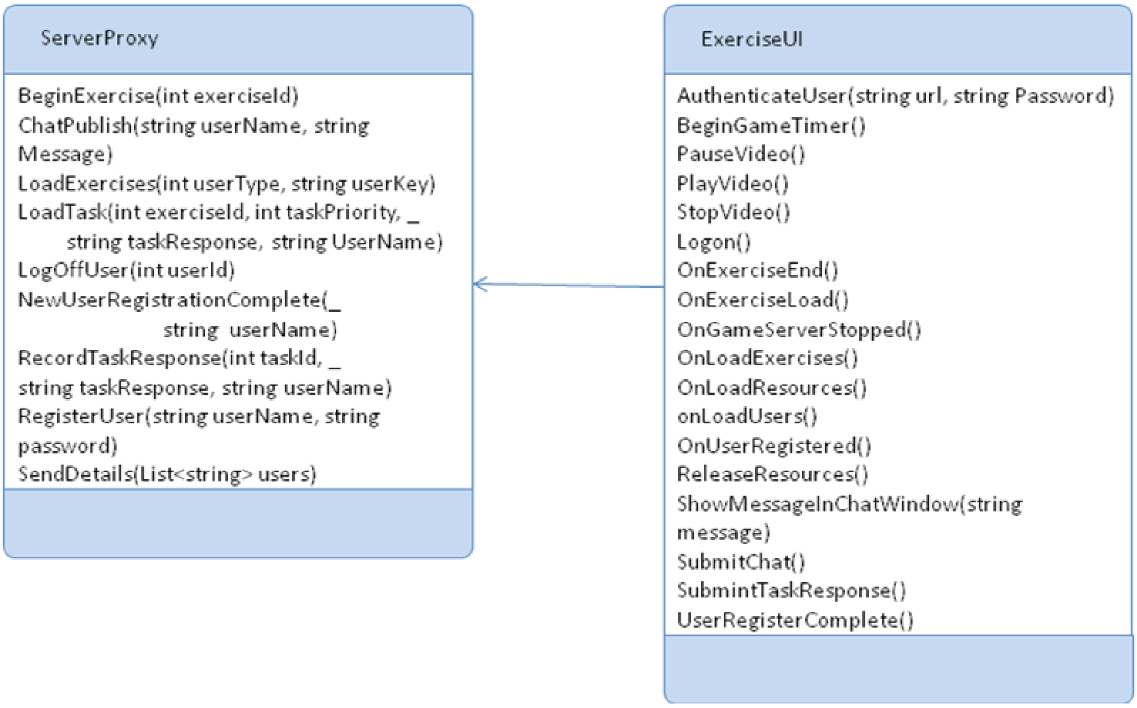
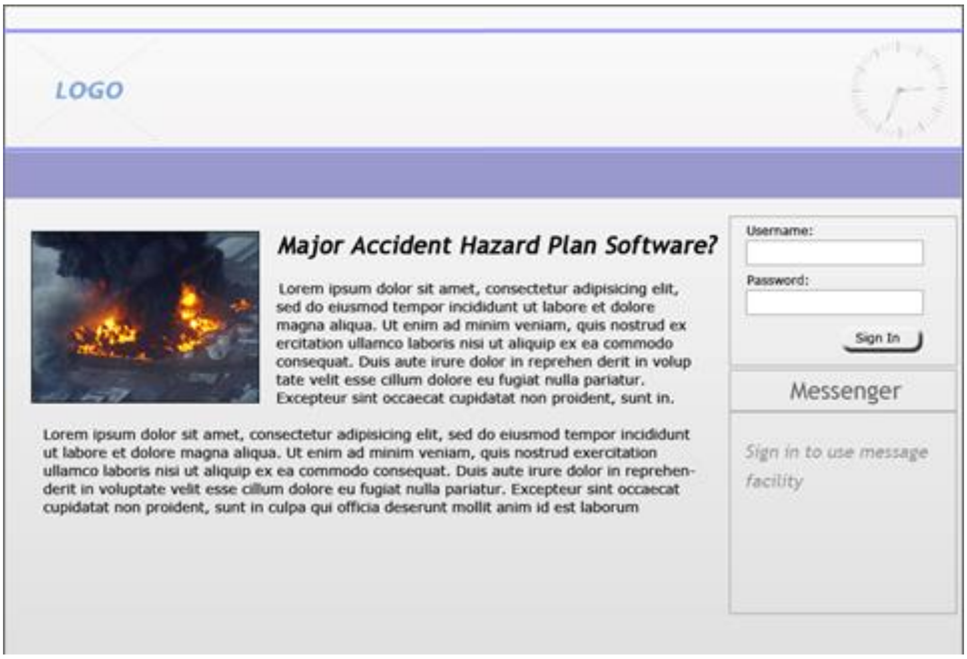


Figure 28 Presentation Layer Classes

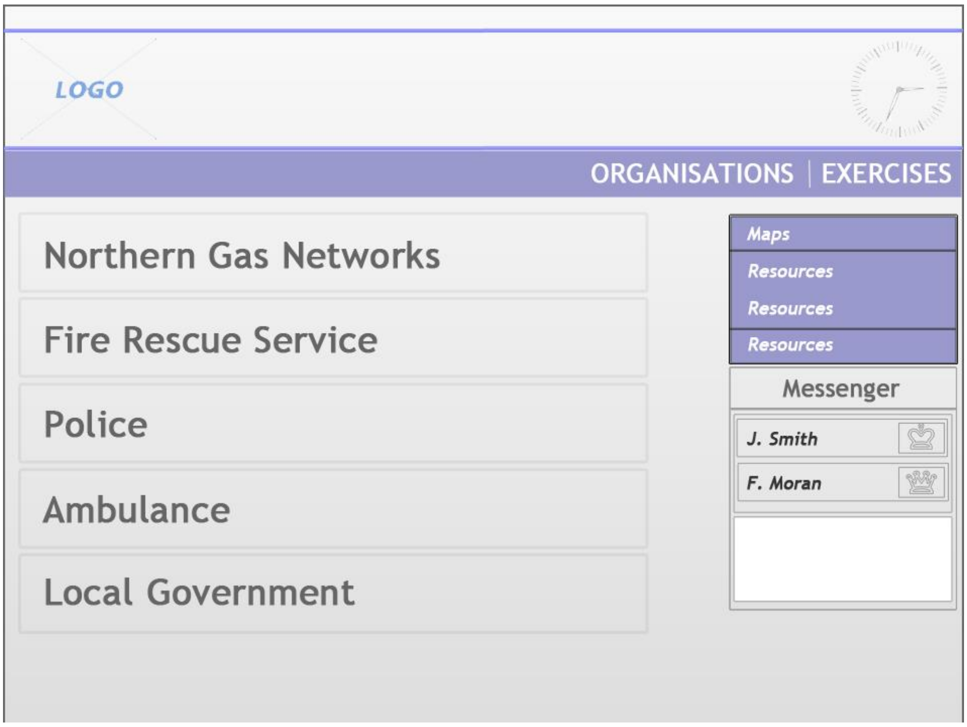
Appendix 7: Wireframe Diagrams

This appendix presents the wireframe diagrams that were used to test the initial flow of information throughout the system with representatives from NGN.

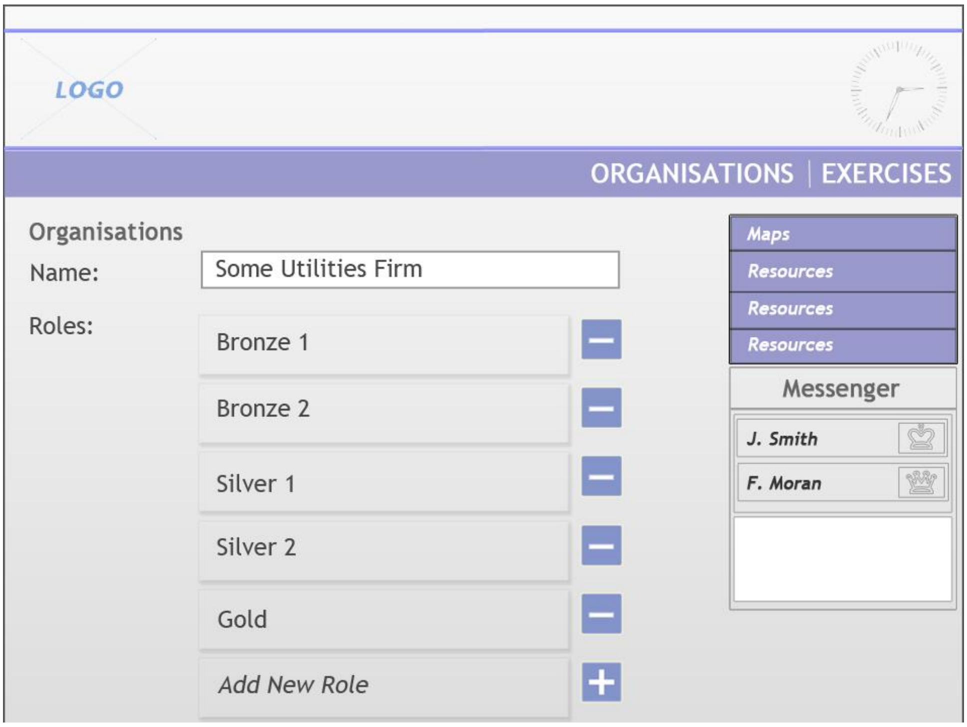


Wireframe 1 – Introduction screen when user not logged in.

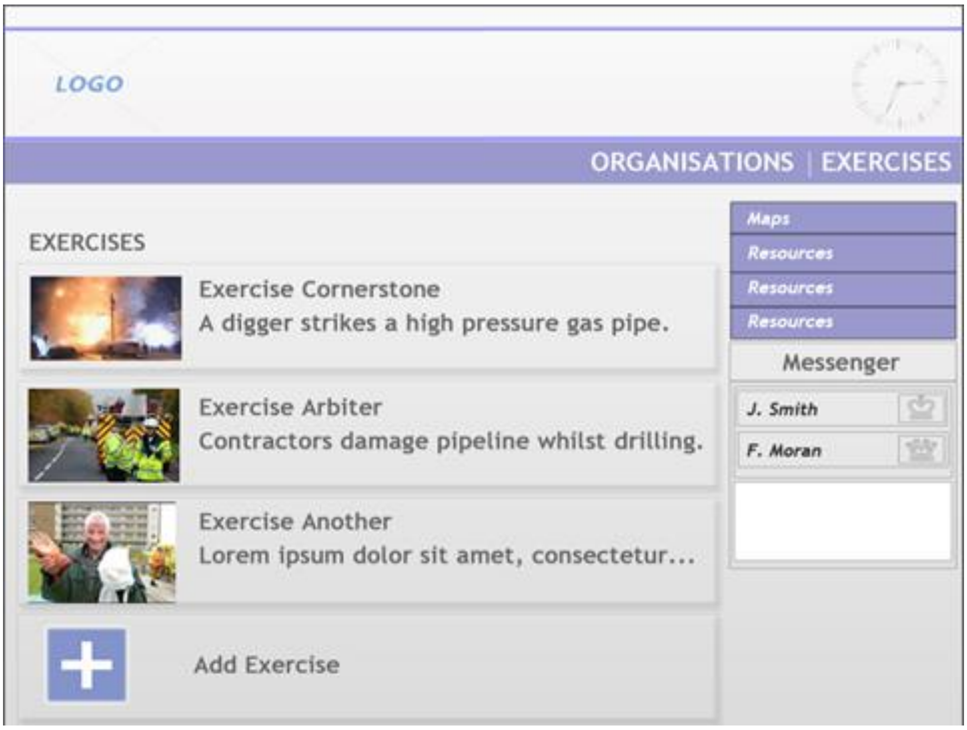
Wireframe 2 – Introduction screen when logged in.



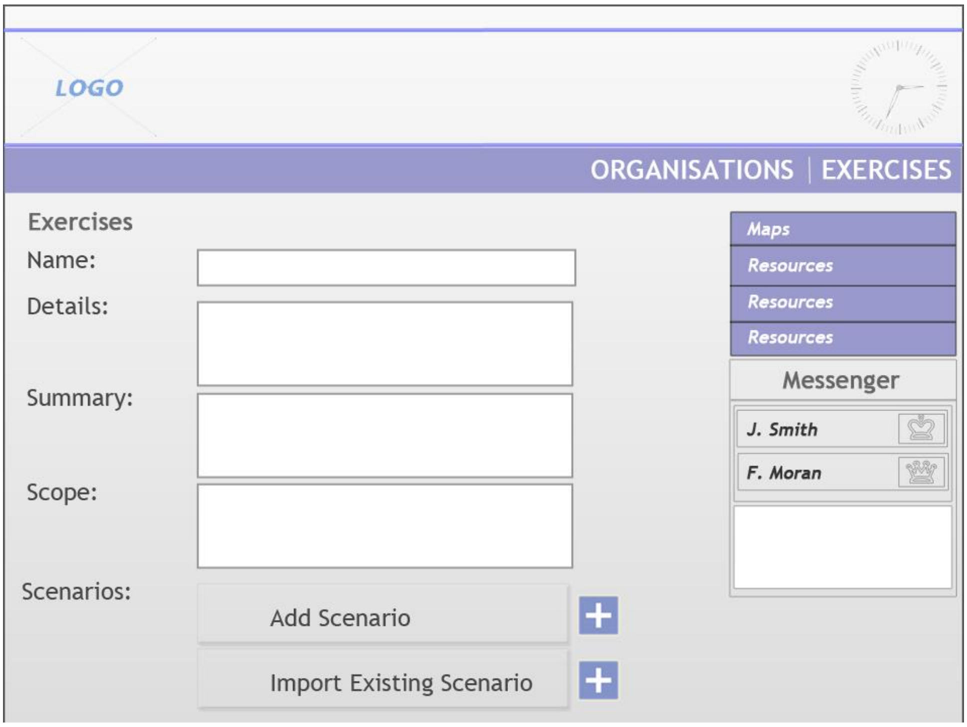
Wireframe 3 – Organisations



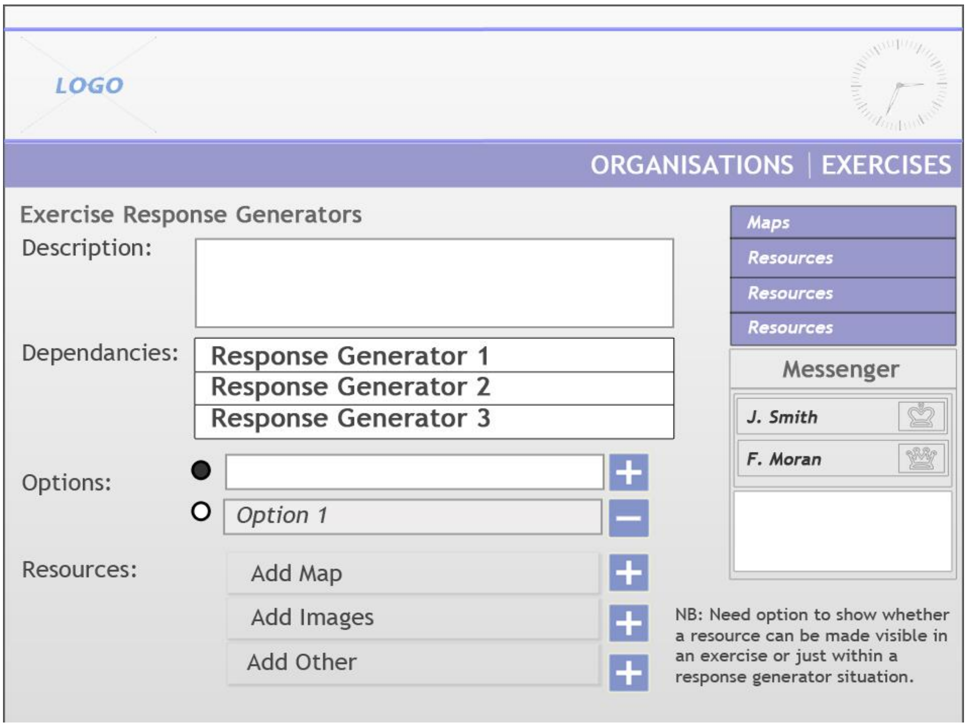
Wireframe 4 – Roles



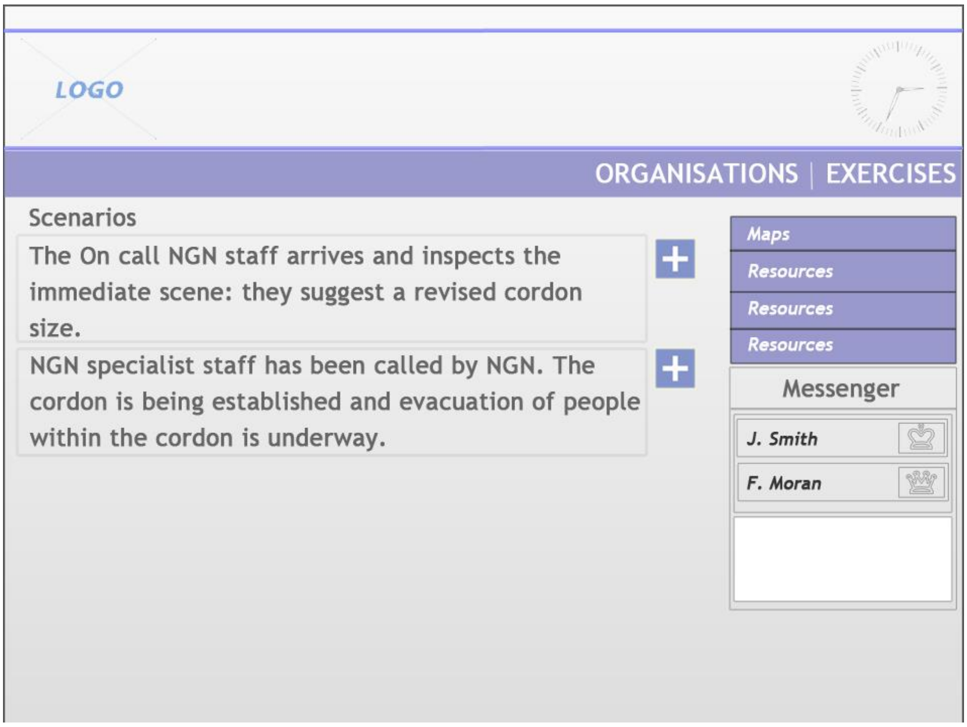
Wireframe 5 – Exercises



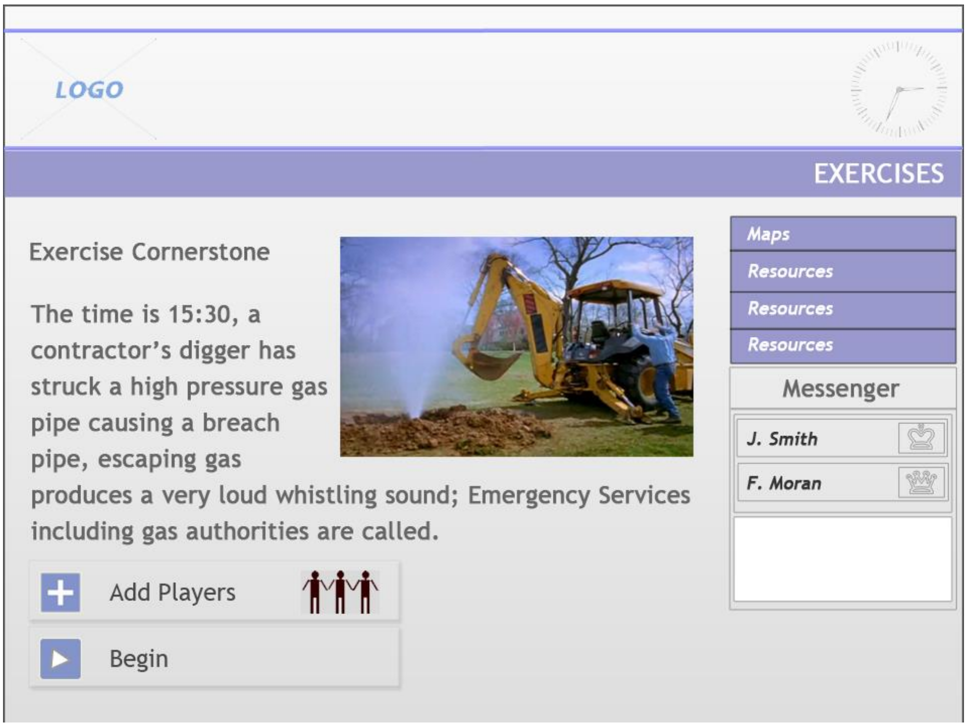
Wireframe 6 – Adding an exercise



Wireframe 7 – Adding exercise response options

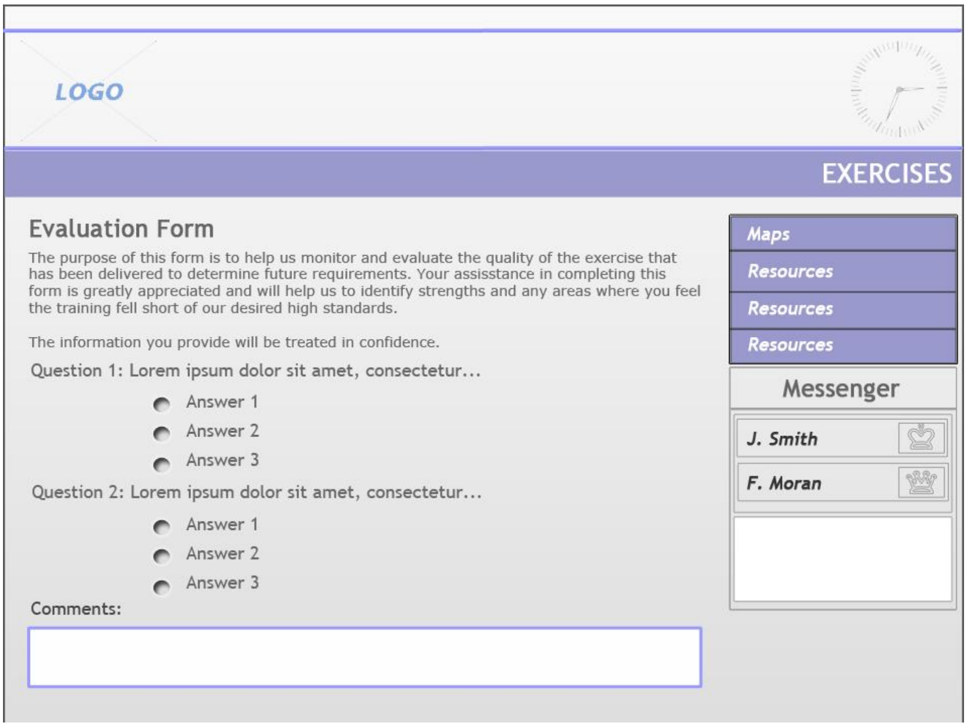


Wireframe 8 - Adding scenarios

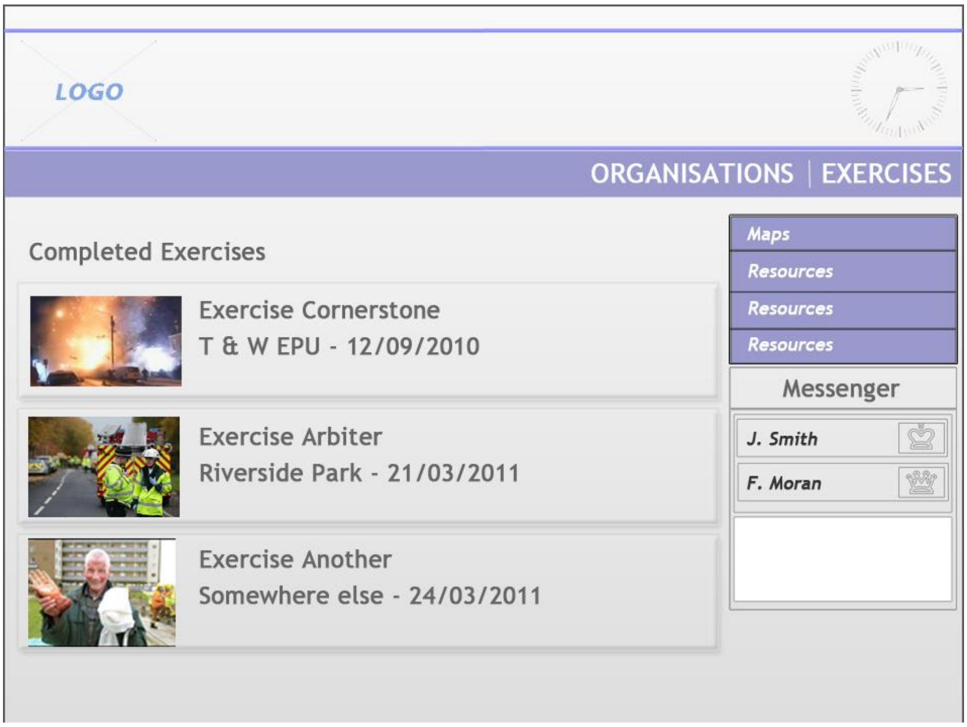


Wireframe 9 – Begin Exercise

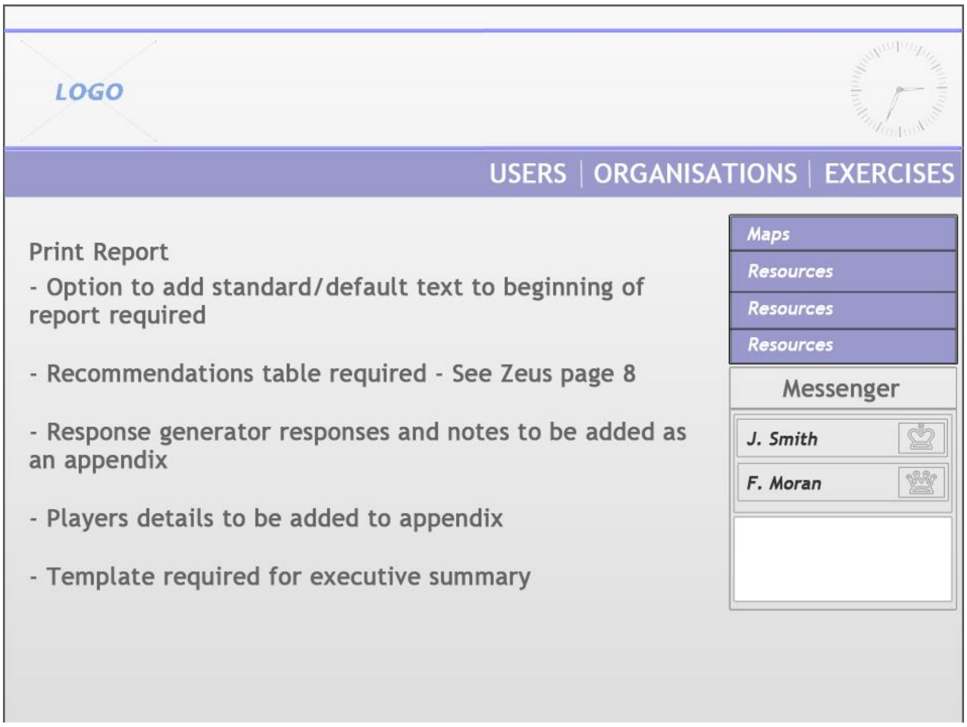
Wireframe 10 – Complete exercise



Wireframe 11 – Evaluation form



Wireframe 12 – Completed exercises



Wireframe 13 – Print report

Appendix 8: Perceived Simulation Deficiencies of Tabletop Role Play Exercises

This appendix presents the perceived deficiencies of the current tabletop role play method as a vehicle for testing and training emergency response planning strategies in comparison to live incident response.

Agency	Role	Response
Fire and Rescue Service	Station Manager	*In an exercise you have the time to discuss with other agencies the best approach to dealing with the task. In a live incident each agency has their own change of command they tend to follow, which usually doesn't include other agencies. There is not necessarily the opportunity to communicate with other agencies because everyone is going about their own business and carrying out their tasks. You also don't have to respond to actions as quickly in an exercise like you do in a live situation.*
Police	Chief Inspector	*It doesn't put the pressure on the decision makers to make decisions, like the Minerva suites[4] do. No time to think about stuff in live incidents, just have to do it.*
NGN	Network Integrity Officer	*There isn't an element of risk, comfort in the fact that you know you're not going to turn anything off or kill anyone. Sound, visual aspects, it's difficult to simulate being in a field when your sat in a room*
NGN	First Call Operative	*The feeling of adrenalin you get when attending a live incident.*

The term “Minerva suites” are a term used to refer to the Hydra simulation software described in Chapter 3.

Appendix 9: Summary of NVivo Coding from Brainstorming Session on Software Experience

Table 34 presents the range of software used by the participants. The references column represents the number of participants who have used the software identified.

Table 34 Software Experience NVivo Coding Template

Name	References
Access	3
Advantex	1
BB Messenger	1
C#	1
Chemdata	3
CIS - intelligent systems	1
Clio	3
CP Uptime	1
Databases	1
Digital Maps	1
Environment Agency Maps	1
Excel	8
F.I.S.H	2
Facebook and Social networking	4
Frontpage	1
GIS	2
Hazard Manager	2
HTML	1
IE	2
Intergraph	1
Internet browsing	2
Itunes & music	3
Java	1
JavaScript	1
Kodak easyshare	1
Lotus Notes	1
Mapinfo	1
Maps	1
Microsoft Project	1
Microsoft Windows	1
Mini tab	1
Mobile Phone Apps	3
Modus image recording	1

	MSN Messenger	1
	NRE	1
	One World	1
	Outlook	8
	P.D.R Pro	2
	Particle Illusion	2
	Photos	2
	PNC	1
	Powerpoint	6
	Publisher	2
	Route Planner	1
	SAP	3
	Scada	1
	SERF	1
	Sharepoint	1
	Skype	3
	Steam	1
	Street View	4
	Systems Analysis	1
	Text Messages	3
	TIMS	1
	Trend	1
	Twitter	2
	Visio	1
	Windows media player & video	1
	Word	8
	X-Box Live	1
	Xoserve	1

Table 35 shows the number of positive and negative comments relating to the PU and PEU of software used by the participants.

Table 35 Applying the TAM to Existing Software Use

	Name	References
	PEU Negative	20
	PEU Positive	47
	PU Negative	4
	PU Positive	16

Appendix 10: Number of Participants that have used the Existing Software Identified

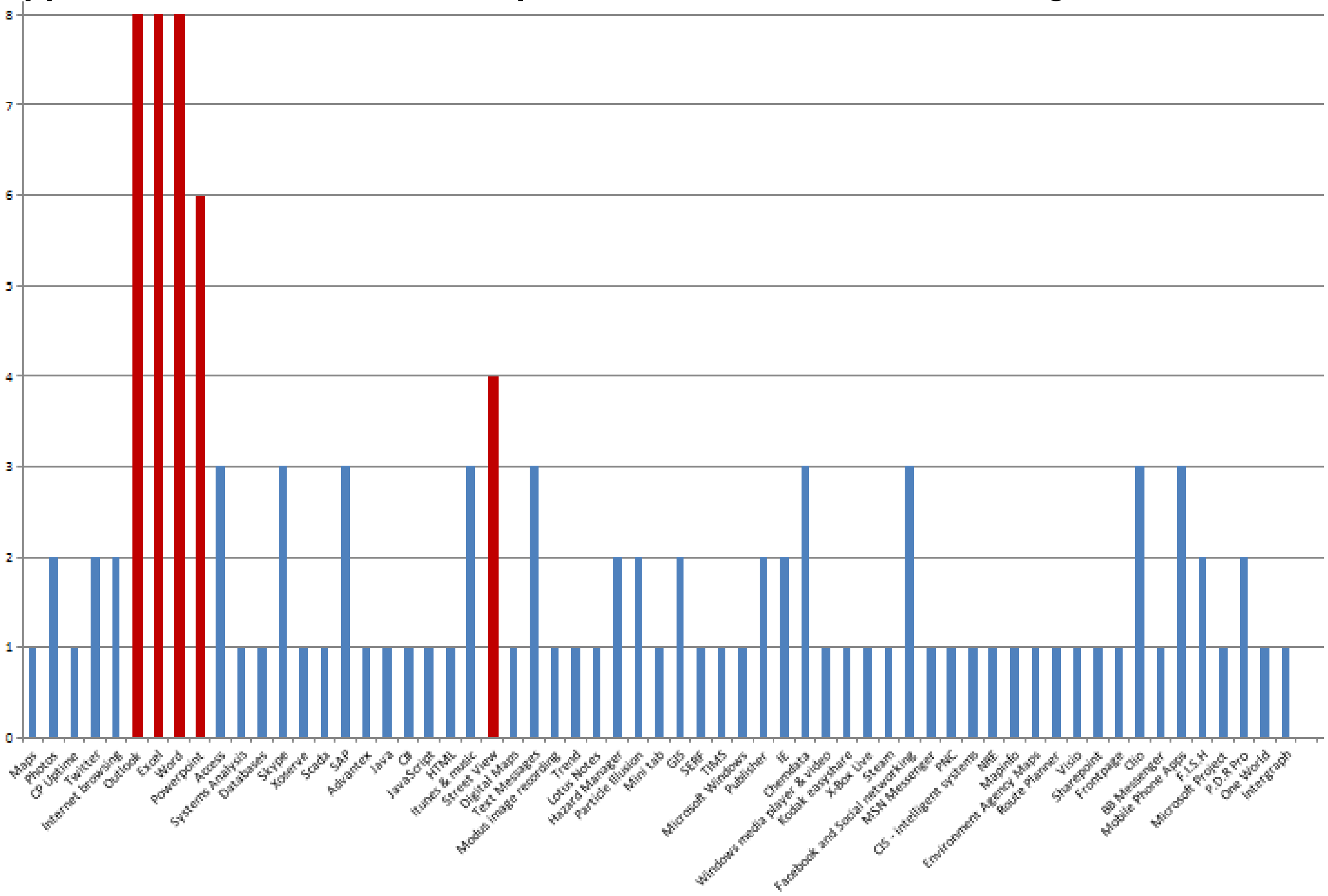


Figure 29 Number of participants that have used the software listed

Appendix 11: NVivo Coding of Positive Attitudes Towards Tabletop Role Play

Table 36 presents the range of comments that demonstrate a positive attitude towards using tabletop role play for emergency planning strategies. The references column represents the number of participants who agree with the comment provided in the adjacent column.

Table 36 Tabletop Role Play Positive Attitudes NVivo Code Template

	Name	References
	Allows more exercises due to timeframes	4
	Allows you to set parameters for exercise i.e. wind speed direction	7
	Bigger Scale Scenarios~Exercises	5
	Brings all emergency services together	8
	cost effective	5
	Easy to control (timeframes)	5
	easy to organise	4
	Faces to names	7
	Good for initial exercise of plan identifies gaps at more economical basis	6
	Good for interchange between parties	8
	Good for testing tactical and strategic decision making	7
	Good for walking through and discussing plans and processes	7
	Good to test individual aspects of a plan that may have been missed by a larger exercise	3
	Less likely to get people injured as part of play	8
	Limited resources required	3
	Mix of experiences	7
	Practice roles - not day job	4
	Reduced disruption to site	2
	TTRP is cost effective	6
	Uncovers any issues in current plans and procedures	3

Appendix 12: NVivo Coding of Negative Attitudes Towards Tabletop Role Play

The range of comments associated with the perceived deficiencies of tabletop role play for testing and training emergency response planning strategies are presented in table 37. The references column represents the number of participants who agree with the comment provided in the adjacent column.

Table 37 Tabletop Role Play Negative Attitudes NVivo Code Template

	Name	References
	Allow people to make unreal assumptions	8
	Allow people to tell ~fibs~ (I would have done….!!)	7
	Allows people to hide behind scenarios	8
	Can't understand the effect of a decision	7
	Communication is easier and maybe unrealistic for a real incident	7
	Cost	4
	Doesn't test plans or processes and procedures named in the plan	6
	Don't always get the operational people	7
	Don't get any familiarisation of site~process	6
	Easy to play lip service	1
	Lack of real time experience	6
	lacks ~real feel~ does not test actual response	7
	No frontline workers involved	7
	No independent review. (only for certain exercises)	7
	No sites used	5
	No urgency	8
	Not a good test of competency	8
	Not dynamic	8
	Perception	8
	Pre-planned to extent	8
	Real examples not used	5
	Tends to stall sometimes	4
	Timeframes easy to manipulate	7
	To many people in the room observing	1
	Unrealistic pressure (Not being put under pressure to make real time decisions	7

Appendix 13: NVivo Coding of the Participants Perceived Expectations of Software Simulation as a Vehicle to Test and Train Emergency Response Planning Strategies

Table 38 presents the range of comments provided by participants associated with their perceived expectations of the software simulation as a vehicle for testing and training emergency response planning strategies. The references column represents the number of participants who agree with the comment provided in the adjacent column.

Table 38 Pre-Evaluation Attitudes Towards Using Software Simulation NVivo Code Template

	Name	References
	All singing all dancing cheap option	1
	Allows individuals to make own decisions and allows consequences of actions	5
	Allows remote participation	5
	Build in custom areas	1
	Build in multiple scenarios	4
	Cost effective for multi-agency working	1
	Creates auditable records	4
	Decision Making Audit trail	1
	Decision Making Tools	2
	Different responses -feedback	5
	Easy to use	1
	Good for training	2
	Instant Feedback	5
	Needs to be easy to use to allow everyone - relevant of ability to use	1
	Perform exercises from different locations	1
	Portable (usually)	1
	Range of scenarios	5
	Realistic views, sounds etc	5
	Record training	1
	Review decision making	5
	Rewind and Review	2
	Stop Exercise	1
	Stop exercise and then re-start	5
	Targets a specific asset	1
	Useful if it's got visual plans	1
	Very good for training	4
	Visual realism	5

Appendix 14: NVivo Coding of Post Evaluation Attitudes Towards Using the Software Prototype

The following table contains the comments documented by the participants during the brainstorming session on their perceived attitudes towards using the software simulation for testing and training emergency response planning strategies. The references column represents the number of participants who agree with the comment provided in the adjacent column. Further comments relating to the participants attitudes towards using software simulation for testing and training emergency response strategies were captured in a voice recording of the evaluation and transcribed. The range of comments from the transcript that were categorised and coded in NVivo can be found in Appendix 15.

Table 39 Post-Evaluation Positive Attitudes Towards Software Simulation NVivo Code Template

	Name	References
	3D better (for me) but it depends on cost against benefit	2
	Allows realistic comm's	1
	Could be used for testing the information coming back to a tactical level	2
	Could put observers in another room	1
	Excellent for operational people	6
	Gives first responders a visual of the incident	4
	Good use for Bronze~ front end operations	4
	Would require different pictures for each role	4
	Useful for Tactical roles	5

Appendix 15: Software Prototype Evaluation: NVivo Coding of Software Simulation Review Transcript

The diagram below represents the key themes emergent from the NVivo coding review process of the transcript that was taken from the recording of the software simulation evaluation.

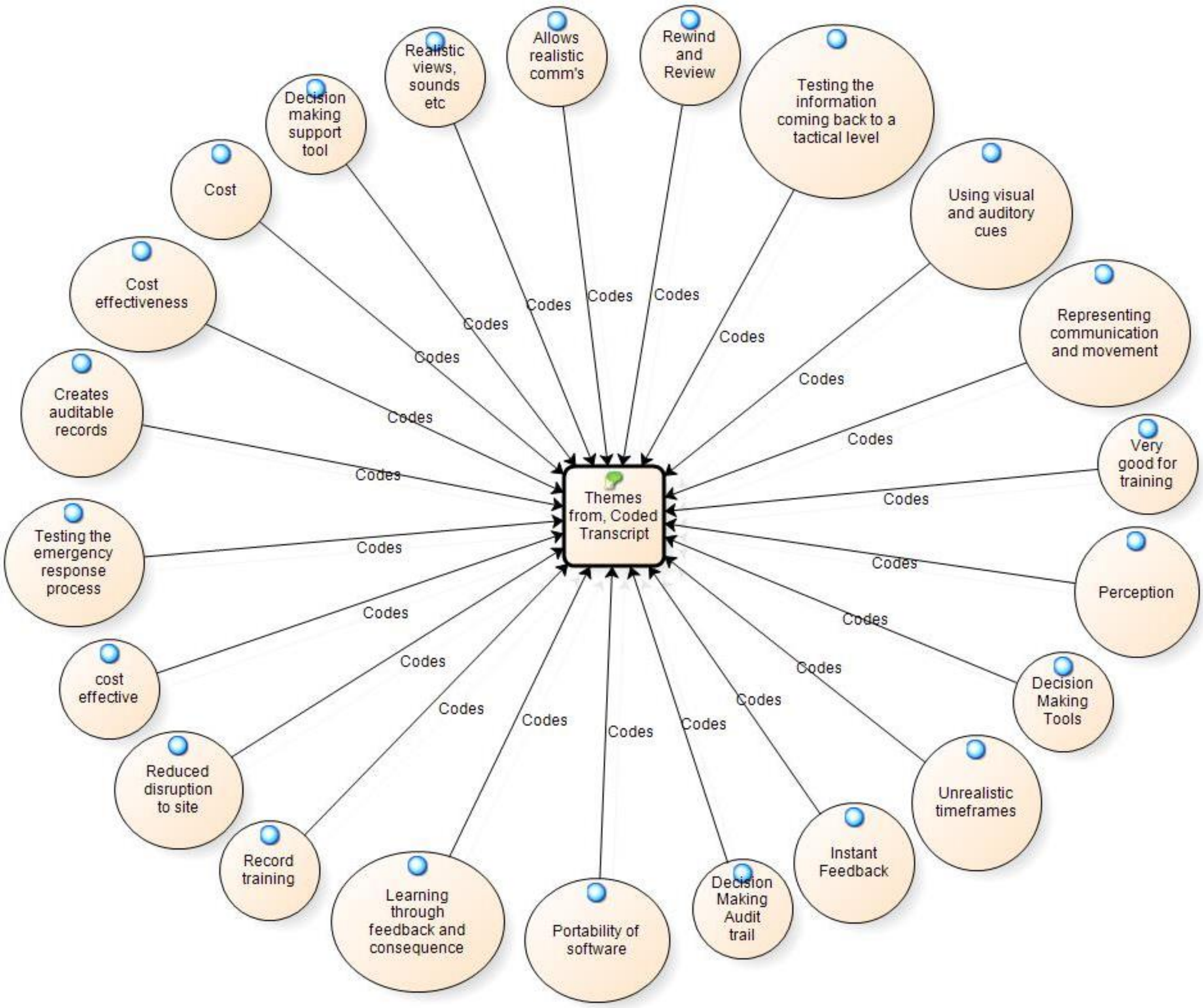


Figure 30 Themes Emerged from Coding Transcripts

Appendix 16: Post Software Simulation Evaluation Questionnaire

Please take a few minutes to fill out this questionnaire on your experiences of emergency planning exercises and software. Your feedback is welcomed and will help to inform a research project being conducted in collaboration between Northumbria University and Northern Gas Networks. The project aims to understand what software simulation can bring to the emergency planning and preparation process. Personal information will not be used in any publications and will be kept confidential. Thank you for your participation.

Personal Information

Providing the following information is optional.

First name: ____________________________ Last name: ______________________________________
Organisation: ____
Job title: ____
Years working for this organisation:________ Years in this role:_________
Telephone: ____________________________
Gender: _______________________________ Age: ______________________

Emergency Planning Exercise Experience

This section of the questionnaire is designed to capture information specific to your experiences of tabletop role playing exercises for testing emergency response plans with multiple agencies. The term exercise specifically refers to exercises designed to test an emergency response plan for a major incident involving a high pressure gas pipeline.

How many exercises have you participated in?

○	○	○	○
0	1	2	3 or more

How many exercises have you participated in the last two years?

○	○	○	○
0	1	2	3 or more

Have you ever been involved in the development of an exercise and if so, how many times?

○	○	○	○
0	1	2	3 or more

Technology Experience

This part of the questionnaire is designed to understand how familiar you are with using technology for work and non-work activities. The term technology refers to any computer applications used on a desktop computer, a laptop, mobile phone, games console or any other type of interface.

1. How often do you use technology as part of your working day?

○	○	○	○	○	○
I don't use it	I use it for 25% or less of my work	I use it for around 25-50% of my work	I use it for around 50% of my work	I use it for around 50-75% of my work	I use it for 75-100% of my work

2. How often do you use technology to conduct activities outside of work?

○	○	○	○	○	○
I don't use it	I use it for 25% of activities or less	I use it for around 25-50% of activities	I use it for around 50% of my activities	I use it for around 50-75% of my activities	I use it for 75-100% of my activities

Communicating with other agencies

This part of the questionnaire is designed to understand how often you communicate with other agencies likely to be involved in a multi-agency response to an incident involving a major gas pipeline.

3. How often do you communicate with other agencies?

○	○	○	○	○
Never	Less than once a month	More than once a month	Weekly	Daily

4. How often do you use technology to communicate with other agencies?

○	○	○	○	○
Never	Less than once a month	More than once a month	Weekly	Daily

5. What type of technology do you use to communicate with other agencies?

____
____
____
____
____
____

6. State your opinion on the following sentence:
"The technology used to communicate with other agencies is the most appropriate for the work I do"

○	○	○	○	○	○	○
Strongly Agree	Agree	Agree Somewhat	Undecided	Disagree Somewhat	Disagree	Strongly Disagree

Please explain why you think this: ____
____
____
____
____

Using Software Simulation to Test an Emergency Response Plan

7. State your opinion on the following sentence:
"I think software simulation of an exercise could be a good for testing an emergency response plan rather than the current method used"

○	○	○	○	○	○	○
Strongly Agree	Agree	Agree Somewhat	Undecided	Disagree Somewhat	Disagree	Strongly Disagree

Please explain why you think this: ____
____
____

8. State your opinion on the following sentence:
"I think software simulation of an exercise could be more likely to prepare participants for implementing the plan at an incident than the current method"

○	○	○	○	○	○	○
Strongly Agree	Agree	Agree Somewhat	Undecided	Disagree Somewhat	Disagree	Strongly Disagree

Please explain why you think this: ____

____

____

____

____

9. State your opinion on the following sentence:
"Using software simulation of an exercise could improve operational staff performance in their job"

○	○	○	○	○	○	○
Strongly Agree	Agree	Agree Somewhat	Undecided	Disagree Somewhat	Disagree	Strongly Disagree

Please explain why you think this: ____

____

____

____

____

10. State your opinion on the following sentence:
"Using software simulation of an exercise could enhance the effectiveness of operational staff in their job"

○	○	○	○	○	○	○
Strongly Agree	Agree	Agree Somewhat	Undecided	Disagree Somewhat	Disagree	Strongly Disagree

Please explain why you think this: ____

____

____

11. State your opinion on the following sentence:
"Using the software simulation could improve tactical staff performance in their job"

○	○	○	○	○	○	○
Strongly Agree	Agree	Agree Somewhat	Undecided	Disagree Somewhat	Disagree	Strongly Disagree

Please explain why you think this: ____

12. State your opinion on the following sentence:
"Using software simulation of an exercise could enhance the effectiveness of tactical staff in their job"

○	○	○	○	○	○	○
Strongly Agree	Agree	Agree Somewhat	Undecided	Disagree Somewhat	Disagree	Strongly Disagree

Please explain why you think this: ____

Can you be contacted again with regards to this research?

○ Yes

○ No

Thank you for taking the time to fill out our questionnaire. Your input is greatly appreciated.

Appendix 17: Post Software Simulation Evaluation Questionnaire Responses

	Emergency Planning / COMAH Officer	Graduate Engineer	Network Integrity Officer	HSE Support Manager/ Operational Manager	Emergency Planner (Senior)	Emergency Planner	Emergency Planner (Senior)	Emergency Planner
Years working on organisation	26	1.5	8	33	29	6 months	2.5	3
Years working in role	5	1.5	0	4	8	6 months	2.5	3
Age	50	23	26	49	46	51	53	28
Number of Exercises Participated in	>3	1	0	1	>3	>3	>3	>3
Number of Exercises Participated in the last two years	>3	1	0	2	>3	>3	>3	>3
Number of times involved in developing an exercise	>3	0	1	1	>3	>3	>3	>3
How often do you use technology as part of your working day	50-75%	75-100%	75-100%	50-75%	50-75%	75-100%	50%	50-75%
How many hours do you use technology outside of work in a day	1-3 hours	Up to 1 hour	Up to 1 hour	1-3 hours	1-3 hours	1-3 hours	Up to 1 hour	1-3 hours
How often do you communicate with other agencies	Daily	Weekly	Daily	<once a month	Daily	Daily	Weekly	Daily

How often do you use technology to communicate with other agencies	Daily	Weekly	Daily	<once a month	Daily	Daily	Weekly	Daily
What type of technology do you use to communicate with other agencies	Email/ Mobile / Landline / Text	Email, Phone, Uptime	Email (Outlook)/ Telephone	Email/ Telephone	Email/ Word/ Texts/ Airwaves	Email/ memo/ letters	Telephone / Email	Email/ Mobile Phone
The technology used to communicate with other agencies is the most appropriate for the work I do	Agree	Agree Somewhat	Strongly Agree	Agree	Agree	Agree	Agree	Agree

Explain why you think this	Email is quick and easy. Telephone is quick and offers a better quality as communication - offers a level of privacy. Email also assists with keeping record of contact and what was discussed	Email documents everything	Email and telephone is all I require	The systems used are compatible with theirs	Usually a realistic method	It's tried and tested, most organisations use it and it's a common theme	It achieves the desired outcome	Email system (outlook) is a good way to send messages to single/ multiple individuals at the same time. Secure email allows plans to be transferred in minutes rather than having to post documents. Emails can also be used as a log for communications
I think software simulation of an exercise would be better than the current method for testing an emergency plan	Agree	Strongly Agree	Strongly Agree	Agree	Agree Somewhat	Agree	Agree	Agree Somewhat

Explain why you think this	If set up correctly can check actual decisions against expected actions.	Interactive, gives concise evidence of exercise. Realism of the incident.	More realistic with actual consequence s recorded	Sights/Sound s used at appropriate points to display progress and outcomes during the exercise	Allows you to see/ hear an incident as it progresses. React more realistic than having to just imagine something - Peoples perceptions	It allows a sense of realism to be put into the exercise dynamics - it can be cost effective and it allows actions/ decisions to be recorded and debriefed at a later date	I agree it should be used as it could be cost effective whilst showing a degree of realism. However it should not be used exclusively as there will always be a need for some live play exercises	For table tops I think this would be really useful however to fully test all aspects of the plan live play is required, issues may arise that can be discovered no other way
I think software simulation of an exercise could prepare participants for implementing the plan at an incident	Agree	Strongly Agree	Agree Somewhat	Strongly Agree	Agree	Agree Somewhat	Agree	Agree Somewhat

Explain why you think this	Provides an understanding of the various types of incident and allows for checking actions, decisions in a safe environment. Cheap/ safe / regards training and development	The participant will be ready to make fast decisions in an incident, as he/she has good experience from the exercise. Adding realism will trigger participant to think back to how he conducted the exercise.	Agree somewhat as nothing can fully prepare you for an emergency situation i.e. noise, fire, explosion	Opportunity to test understanding and feel pressures exerted from various areas during the management of an incident	They could go through the actions of the plan and see/ demonstrate any issues etc	Its only part of the whole package - realistic training could be used to enhance simulation but it's a good start for future development.	I agree it can help prepare people however it should be part of their training	Again no substitute for live play, software would give a good initial background to expected actions

Appendix 18: TAM Theme Analysis from Prototype Evaluation

Table 40 shows the number of references relating to the TAM constructs AT, PEU and PU that emerged from the coding of the transcripts and brainstorming data captured during and after the user acceptance evaluation of the software simulation.

Table 40 Results from Prototype Evaluation for TAM Theme Analysis

	Name		References
	TAM Themes		
		AT	1
		PEU	16
		PU	112

Appendix 19: Publications

Rogage, KA. (2013), 'Preparing for Emergencies through Stimulating Simulation', Dealing with Disasters International Conference, Northumbria University, Newcastle upon Tyne. 4th - 6th September 2013.

Rogage KA. (2012), 'An Evaluation of Software Simulated Environments for Emergency Response Planning', Northumbria University Research Conference, Northumbria University, Newcastle upon Tyne. 16th -17th May 2012.

Rogage, KA. (2011), 'The Role of Software Simulation in Preparing Emergency Responders for Incidents Involving the Gas Infrastructure', *Proceedings of North East Asia –UK International Conference and Study Tour on Adaptation for Safer Cities*, Northumbria University, Newcastle upon Tyne. 5th-7th September. Northumbria University, Available at: http://www.preventionweb.net/files/22447_22447adaptationforsafercitiesconfer.pdf (Accessed: 30th October 2013).

Rogage KA. (2011), 'A Methodology for Evaluating User Experiences of Software Simulation in Preparing for Emergencies', *Northumbria University Research Conference,* Northumbria University, Newcastle upon Tyne. 5th - 6th May 2011.

Rogage, KA. (2010), 'Preparing Emergency Response Teams for dealing with Disasters in the Gas Infrastructure', Dealing with Disasters International Conference, Northumbria University, Newcastle upon Tyne, 23rd-24th November.