INFORMATION REQUIREMENTS GATHERING FOR ON-SITE EMERGNECY RESPONSE SYSTEMS

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Abstract

The establishment of any on-site information systems for emergency response operations heavily relies on the gathered information requirements. This paper investigates information requirements gathering methodologies and demonstrates them through the design of an on-site emergency response information system. The research method is based on a form of cognitive task analysis, called Goal-Directed Task Analysis. The work starts with the identification of typical incident scenarios and then derives four general categories of information requirements. Information requirements of core members in emergency first response are gathered through extensive semi-structured interviews with fire fighters together with observation made of fire emergency response training simulations. These core members are incident commander, sector commander, BA entry control officer, and BA wearer. The information gathered have been presented in a prototype of an on-site information system for emergency response, and evaluated by appropriate subject matter experts (SMEs).

1. Introduction

Improving the capability of responding to man-made or natural disasters has attracted many attentions since September 11 terrorist attack on the USA Word Trade Centre and the July 7 London bombing, and has been highlighted by the recent Wenchun earthquake in China. Man-made or natural disasters share a common feature that is people do not know when and where the disasters will happen in advance. Therefore, the faster the emergency responders are able to gather, analyse, and act on key information, the more effective their response will be, the better the needs will be met, and the greater the benefit to all affected people. The emergency commanders must make critical decisions at the onset of a disaster, and the quality of these decisions in turn depends upon the timeliness together with the amount and accuracy of the information available to them. It has been argued that good decision-making relies on the information available and the ability of decision makers to cope with the demands

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imposed upon them. The aim of this paper focuses on identifying information requirements for on-site emergency response systems.

Rich literature exists in the area of emergency response information system design. Turoff, Chumer, Van de Walle, and Yao (2004) developed a set of eight general design principles and three supporting considerations for a dynamic emergency response management information system. These principles cover not only emergency response but also off-site activities such as system training and simulation. The uncertainties and the stress of decision-making during emergency response have been recognised as highly important in Turoff's general design principles. Yang (2007) proposed an on-site information sharing infrastructure for emergency response management. Situation awareness has been applied in the information presentation for on-site emergency response system design in the recent work of Yang et al. (2009). A low-fidelity prototype of large displays for incident command (Jiang et al, 2004) demonstrated the most useful features of on-site emergency response systems in the information presentation, including location tracking, area maps, fire status, and resource allocation et al. There is also a great deal of existing field studies of the fire emergency response carried out in the community (Kyng, Nielsen, and Kristensen, 2006; Landgren and Nulden, 2007). Methods for obtaining this data include observing a training exercise in the field, eye-witnessing real incidents, carrying out interviews, and iterating on several low-fidelity prototypes. Two typical lessons have been learned from these field studies. Firstly, in emergencies, all activities need to be focused on the people and environment around them rather than on any particular devices. Secondly, redundancy is important for emergency response in improving communication and safety.

The rest of the paper is organised as follows: Section 2 describes the information requirement gathering methodologies and the scenarios. Section 3 presents four general categories of information requirements for emergency response. The details of the information requirements of core fire crews are given in Section 4. The concluding remarks are presented in Section 5.

2. Research methodologies and emergency scenarios

Our research method is based on a typical Cognitive Task Analysis (CTA), called Goal-Directed Task Analysis (GDTA) (Albers, 1998). As a CTA, GDTA recognises the importance of understanding goals rather than the physical tasks, and is clearly driven by the operator goals or cognitive demands. GDTA is predominantly an interview-based method. According to the application guideline, starting from the first interview, users of GDTA first visualise the goals followed by the decisions taken to achieve such goals and finally derive the information needed to make the decision. Being an iterative type of an approach, identified goals, decisions and the information requirements can be improved further by conducting a series of interviews with appropriate subject matter experts.

In the selection of interview methods for information requirement gathering, the following constraints were taken into consideration: firstly, fire and rescue workers are extremely busy and unpredictable in their availability, especially the operators who are much closer to the actual fire fighting; secondly, these operators are more used to identify their tasks rather than their goals. Therefore meeting them regularly and getting them on the desirable directions would be difficult. In addition, the possibility of organizing a number of group meetings for the same set of participants would also be hard. Thus semi-structured interviews were conducted with fire crews in three local fire and rescue services, guided by pre-defined scenario. Four core roles carried out by fire crews in the UK fire and rescue organisations were identified and representatives were interviewed. The roles were front line fire fighters, entry control officer, sector commanders, and incident commanders. The interviews were made with one individual at a time in fire brigades and took 90 minutes on average. Each interview was recorded using a digital recorder and transcribed afterward.

Table 1: Scenarios used for semi-structured interviews

Scenarios	Type of Building	Time	Location	Causality	Description
1	Shopping centre	3:00PM on week day	2nd floor	No causality	999 call has been received from the Westfield Command & Control specifying the fire. No causality is reported.
2	Domestic dwellings	0:00AM on week day	4th floor	Several causalities	999 call has been received from the bath Street Community Housing Security specifying the fire. There are several causalities being reported. The fire seems to be spreading form its original to different flats in the same floor.
3	Hospital	5:00PM on Sunday	5th floor	Few causalities	999 call has been received from the Royal Infirmary Nurses Quarters Warden specifying the fire. There are few causalities being reported. Fire seems to be contained to a single dormitory on the 5th floor.
4	Industrial estate	10:00AM on week day	Manufacturing plant	No causality	999 call has been received from the fire fighting unit at Rolls Royce, asking support with the detail of the fire. There are no reported causalities. Laboratory may consist with harmful chemicals and radioactive materials. Fire seems to be spreading from its origin to other parts of the building.

The four identified scenarios summarised in Table 1 are described in terms of the types of the buildings concerned and used to guide the interviews. Variations in the time of the incident

and the location of the reported fire were introduced into the scenarios during the interviews for crosschecking the responses of the fire crews. Each interview begins with an introduction of the purpose and intent of the data collection effort. A set of the above scenarios are selected and presented to the emergency personnel. The interview questions and responses are elicited and structured in the form of Goal-Directed Task Analysis. In this analysis, the major goal of the on-site emergency information system was identified as 'leading to situation awareness of selected core members of the UK fire-fighter hierarchy', together with any major sub-goals necessary for meeting this goal. Any major decisions, associated with each sub-goal, that need to be made were identified through the interviews. The information requirements needed for both making these decisions and carrying out each sub-goal were also identified. Primitive interview probes and intermediate validations were added in the Goal-Directed Task Analysis. In the following two sections we present the information requirements gathered from these interviews, literature studies, and other forms of field studies.

3. Four general categories of information requirements for emergency response

In this section the general categories of information needed in an emergency response are identified. This section is based on previous published material (Fire Service Manual 1999), prior research (Prasanna, Yang, and King 2007; Yang 2007), and extensive interviews carried out with fire fighters and the observation of fire emergency response training simulations in three fire and rescue services (Derbyshire, Leicestershire, and Loughborough) in the East Midland region in the UK. Many of the categories identified equally well applied to large-scale natural disasters as well as to fire incidents. The objectives of an information system to support emergency response is to focus on providing support to incident commanders in decision making, guiding and protecting emergency front line responders in response operations, and protecting members of the public who may be located in or near in the disaster scene. The faster the emergency responders are able to gather, analyse, share, and act on key information, the more effective their response will be, the better the needs will be met, and the greater the benefit to all affected people (Van de Walle and Turoff 2007). Jackson (2006) summarised information requirements for protecting emergency responders in his speech to the Government Reform Committee of the United States House of Representatives. Though managing overall emergency response has a broader set of information requirements, Jackson pointed out that the key pieces of information to guide decision making were information about the hazard environment, information on the responder workforce, information on evolving safety issues, and information about safety equipment. Our research (Yang 2007) and interviews with fire fighters show that the following four categories of information require collection, sharing and presentation in an on-site information system, not only for protecting emergency responders, but also for ensuring the success of the emergency response operations.

- Category one: environmental conditions

When the first responders arrive at the incident scene, they have very limited information about the environment, such as the building infrastructure, number of occupants or the exact location of the hazard. Furthermore, they do not know whether the building/underground station is safe to enter or how to most efficiently deal with the hazard. Many front line responders may be facing unfamiliar hazards. Decision makers need to know of these hazards and have an overview of the environmental conditions. Then they can consider a plan to deal with these hazards before they dispatch their responders to cope with them.

- Category two: information on response participants

Some disaster situations involve many hundreds of individuals from different organisations cooperating in the response. Knowing who is involved in the response, what capability they are offering, and what resources they are bringing to the scene gives incident commanders information to enable them to determine the most effective and coordinated approach to the situation.

- Category three: status of casualties

Obtaining and rapidly sharing among involved organisations the latest casualty data, and reporting accident locations, causes and severity among involved organisations is critical to ensure the responders can take appropriate rescue measures and quickly coordinate emergency medical services during the response.

- Category four: available resources

Once a major disaster occurs, large amounts of equipment and other resources are quickly delivered to the area by many governmental and non-governmental organisations. Often there is no central control or storage for the equipment. Collecting and sharing information about available equipment is critical to ensuring responders find what they need from the stock of equipment which has arrived at the incident scene. Ensuring that responders have the equipment they need becomes more difficult in the charged and high-pressure atmosphere of an on-going disaster response. Since many different organizations may be involved in managing logistics, a central information management system is needed for tracking what equipment is in use, where replacement supplies are available, and how to match them to individual responders' needs.

4. Information requirements of core fire crews

The previous section identified four general categories of information to support emergency response to a variety of disasters. These clearly apply to fire incidents, as a particular type of disaster. This section now focuses specifically on fire incidents in and around large scale structures, and considers the end user requirements analysis for key personnel who act as first responders in such an emergency situation.

Initial explorations of the literature related to the UK emergency first responder hierarchy, three observations made on the first responder training activities, fifteen interviews with subject matter experts in fire and rescue services, and one shadowing incident response led to the identification of four types of important end-users of on-site emergency information systems in the first responder hierarchy, namely: Incident Commanders, Sector Commanders, Entry Control Officers and Front Line Fire Fighters. Other job roles, apart from these core members of the first responder team, are commonly considered to be introduced mainly to maintain the appropriate span of control so that they will reduce both the mental and physical workload of the core members. Therefore any on-site support system should essentially look after the needs of these four types identified above. The Fire Service Manual (1999) reveals that the requirements of other emergency response members are a subset generated from the combined requirements of these core members. Therefore, it is reasonable for us to assume that if any on-site information system is able to meet the requirements of these four types of core members, it could easily be adapted to assist any other supporting roles in the fire and rescue operation.

Interviews were carried out with subject matter experts extracted from each of the four groups of responders, and these led to a successful elicitation of their dynamic information requirements during an emergency response. The accuracy of these information requirements was strengthened by testing against the procedure and policy documents, the findings of the field studies carried out by other researchers in the community, and the findings of the observations made during fire and rescue training activities. The information requirements of different job roles in the fire fighter hierarchy are summarized below.

4.1 Information requirements of a front line fire fighter

The information requirements of the front line fire fighter include:

- Information on the immediate surroundings of the fire fighter, for example, environmental temperature, smoke and CO concentration behind a door, and any possibility of building structure collapse or other critical dangers.
- Information on the fire fighter's body health, including body temperature, rate of breathing, the probability of them getting lost inside a building, running out of oxygen, or suffering from extreme exhaustion.
- Information on casualties, including where and how many causalities are trapped inside an accident building, condition of the identified casualty (dead or alive), suitable location for keeping casualty till evacuation.
- Information on other crew members, such as body health of fellow fire fighters and their location.
- Overall contextual information on the sector they are operating in, such as any announcement from a sector commander and information on operational activities being carried out in the vicinity.
- Information on fixed resources and installations around the area of operation, such as sprinklers, ventilation outlets, water drains, fire fighting shafts, wet and dry riser outlets.
- Information on welfare, such as where to find food and choice of food, water, the expected duration of work and arrival of any relief.
- Information on the assigned tasks and resources, including the physical boundary of the assigned tasks, expected result, appropriate personnel protective equipment and special equipments available for use.
- Information on any hazard material together with their characteristics and identification.

Their requirements also include the following real time alarms:

- Out of range alarms,
- Health alarms,
- Evacuation alarms,
- Out of route alarms relevant to an individual front line fire fighter,
- Environmental alarms such as possible back draughts or flashovers.

The interviews also highlighted several information needs of the front line fire fighters, which are considered as essential to provide them with higher levels of situation awareness (SA). These higher level SA requirements can be described as:

- Search and rescue route options, i.e. possible routes to search and rescue any trapped people inside a building, routes to the source of the hazard (fire), routes to the items to be salvaged.
- Real time navigation support. Finding the way out of a potentially dangerous place is a crucial task for fire fighters especially when working with breathing apparatus that can provide support for only a very limited amount of time. Real time navigation system supports fire fighters enabling them to fulfil their mission and return safely.
- Alternative route options due to contextual change. If the pre-defined route has been made unusable due to the environment change what is the alternative route to complete the assigned task?
- Dynamic contextual changes along the route: spread of fire and other hazards, occurrence of new risks and hazards.

4.2 Information requirements of entry control officers

Entry control officers are the team leaders of front line fire fighters. All the information listed as required by the front line fire fighters should also be available to an appropriate entry control officer. In addition, entry control officers need some additional management information such as:

- Evacuation status of individual front line fire fighters,
- Assigned profiles of individual front line fire fighters,
- Tasks assigned for an entry control officer,
- Assigned resources and new resource requests, such as availability of emergency back up teams, number of fire fighters to be withdrawn and available backups,
- Completed search and rescue efforts,
- Status of the ongoing search and rescue efforts,
- Suitable entry control points and their locations,
- Contamination levels of evacuated fire fighters,
- Information on nearby entry control points and the current operations.

To protect their front line fire fighters entry control officers need the following real time alarms:

- Evacuation failure alarms,
- Alarms due to unexpected route changes of the front line fire fighters,
- Duty assignment alarms.

4.3 Information requirements of sector commanders

A sector commander is in charge of a sector in an incident scene and co-ordinates the response activities of a number of entry control officers who belong to the sector. A sector commander requires the same information, including the real time alarms as that of an entry control officer. However more information is required by a sector commander to cover the whole sector and provide a summary of the status of all the front line fire fighters. In addition, the context forecast and determination of ventilation locations are essential to higher level decision support for the sector commanders. In detail additional information for sector commanders include:

- Assigned physical and human resources to the sector.
- Level of work difficulty for officers within the sector.
- Resource consumption of essential resource within the sector, such as water and foam.
- Information to identify hazard materials and contaminants within the sector, such as relevant hazard material data.
- Tactical mode for the sector.
- Summary of contextual hazards within the sector, including source, location, level of spread, spread forecast.
- Summary of fixed installations within the sector, such as dry and wet riser outlets, sprinklers, fire alarm panels, controls of electricity and gas.
- Location of suitable drains for waste water.
- Information on availability of expert support for the sector, such as contact and location details of safety officers, paramedics, decontamination officers, location of triage and first aid.
- Competence of allocated officers and fire fighters.
- Requirement availability and location of welfare, for example food and water.
- Status of physical and human resource requests, for example location and movement of fire engines, expected time of arrival.
- Information on items to be salvaged, such as description of items, ranking of items to be salvaged, handling advice and their location.
- Information on decontamination requirements within the sector, for example level of decontamination and required level of personnel protective equipment (PPE)
- Information on construction and structure of the building, for example age and building materials.

4.4 Information requirements of an incident commander

An incident commander is the most senior staff member at the incident scene and is responsible for all the sectors of an incident. The information required by an incident commander includes an incident summary report and access to detail when necessary. The incident commander also needs to be aware of all relevant information about the activities and capabilities of other participating organizations. The incident summary report periodically provides the overall status of the incident, such as the number of casualties being rescued, injuries, deaths, tactical mode changes, sector details, etc. Information for making the initial risk assessment and ranking casualties at the incident is identified as a unique situation awareness need for the incident commander. Additional information for the incident commander on top of sector commander requirements includes:

- Information on external water resources, such as public and private pools.
- Detail information on vulnerable buildings around the vicinity of the incident, for example power plants, petrol stations, schools, and hospitals, and details of their operations.
- Information on overall progress of search and rescue, fire and salvage operations, such as rate of rescue and salvage, increase or decrease of spread of fire.
- Information on surrounding domestic population, such as population density, location.
- Information on nearby environment to be protected, such as water sources and wild life.
- Weather and weather forecast around the incident, especially the wind condition.
- Information on traffic arrangements around the incident.
- Information on incident terrain, for example ground slope.
- Information on the overall incident hierarchy.
- Contact information of incident specific specialists, such as architectures, engineers, safety officers.
- Information on building occupiers, such as type of occupiers, useful historical behaviour, for example evacuation reluctance.
- Information on sectors, external boundaries and cordons, such as hazard zone, operational safety zone, public evacuation zone.

4.5 Hierarchy of information requirements and implementation

The information requirements of individual core members in the emergency response team can be organized into a hierarchy which is evolved from the chain of command of the fire with strict ranks and roles. The rank increases upwards, from the front line fighters, the entry control officers, to the sector commanders, and then to the incident commanders. The information requirements of front line fire fighters form the most basic part in the hierarchy and are located at the bottom. All the information requirements of front line fire fighters are fed into entry control officers. Control commands from the entry control officers are sent to the front line fire fighters. Similarly, the entry control officers and the sector commanders feed their information to, and receive the control commands from, their direct commanders. Incident commanders are at the top of the hierarchy and hold all the information about the incident, including the status and capabilities of other participating organizations. This hierarchy organizes information requirements in terms of the emergency first responder's goals, rather than presenting them in a way that is technology-oriented.

The above identified information requirements have been implemented in an under-development emergency response system, an information infrastructure to enable building, fire fighters, fire engines, and their control centre to wirelessly communicate with each other during natural or man-made disasters. The information is presented to various fire crews at perception, comprehension, and projection levels in order to achieve best situation awareness

(Yang et al., 2009). The prototype of the system has been evaluated and validated by appropriate subject matter experts.

5. Concluding remarks

On-site emergency response systems are needed to provide information on environments, casualties, response participants, and available resources that will allow incident commanders to make accurate decisions for efficient emergency response. On-site emergency response systems must support the decision making of emergency responders in a charged, high-pressure and stressful atmosphere. Our research has identified the four key end-users of on-site emergency response systems as incident commanders, sector commanders, entry control officers, and front line fire fighters. Each of these end-users has unique information requirements that have been explored according to Goal-Directed Task Analysis. These information requirements are organised in a hierarchy which is consistent with the para-military organisation in the UK fire and rescue services. We believe that the information requirements derived for fire incidents are also applicable to other emergency response as well because of the common features of these disasters.

References

Albers, M.J., "Goal-Driven Task Analysis: Improving Situation Awareness for Complex Problem-Solving", Proceedings of the 16th annual international conference on Computer documentation**,** Quebec, Canada, 1998, pp. 234 - 242.

Fire Service Manual - Volume 2 - Incident Command. Crown Copyright, UK, 1999.

Jackson, B.A., "Information sharing and emergency responder safety management", http://www.rand.org/pubs/testimonies/2006/RAND_CT258.pdf, 2006.

Jiang, X., Hong, J. I., Takayama, L.A., and Landay, J.A., "Ubiquitous computing for firefighters: Filed studies and prototypes of large displays for incident command", In the Proceedings of ACM conference on human factors in computing systems, Vienna, Austria, 2004, pp.679-686.

Kyng, M., Nielsen, E.T., and Kristensen, M., "Challenges in designing interactive systems for emergency response", In the Proceedings of 6th ACM conference on desiging inteactive systems, University park, Pennsylvania, USA, 2006, pp. 301-310.

Landgren, J., "Making action visible in time-critial work", In the Proceedings of ACM conference on human factors in computing systems, Montreal, Quebec, Canada, 2006, pp.201-210.

Prasanna, R.K.R, Yang, L., and King, M., "Integrated Information Management System Model for Emergency Response", In the proceedings of the 13th International Conference on Automation and Computing, Staffordshire University, England, September 2007, pp. 59-64.

Turoff, M., Chumer, M., Van de Walle, B., and Yao, X., "The design of a dynamic emergency response management information system", Jouranl of Information Technology Theory and Application, 2004, 5:4, pp. 1-36.

Van de Walle, B. and Turoff, M., "Emergency response information systems: emerging trends and technology", Communications of the ACM, 2007, 50:3, pp. 29-31.

Yang, L., "On-site Information Sharing for Emergency Response Management", Journal of Emergency Management, 2007, l5:5, pp. 55-64.

Yang, L., Prasanna, R.K.R, and King, M., "Situation awareness oriented user interface design for fire emergency response", Journal of Emergency Management, 2009 (in press).

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