Describing Pipeline Emergency Response Communications Using Situational Awareness Informational Requirements and an Informational Flow Analyses

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ABSTRACT

The Christian Regenhard Center for Emergency Response Studies at John Jay College, CUNY, has begun work on developing best practices for hazardous material pipeline emergency response plans. The approach involves modeling a generic goal-based interagency emergency communications system using a two-step process. First, a situational awareness information requirements analysis will describe the informational requirements essential to an effective emergency response. The requirements analysis involves a goal decomposition approach where the information requirements are related to actionable decisions, goals and emergency response roles. Second, an information flow analysis will informational sources and means to provide required information. The same panel of experts will complete both analyses. Once the communications system is described, a separate Delphi group will use a failure modes and effects analysis (FMEA) to estimate the criticality of the components described in the situational awareness requirements and information flow analyses.

Keywords

Situational awareness, communications, emergency response, pipelines

INTRODUCTION

Pipeline emergencies involve unusually difficult communications challenges. Pipeline emergencies can occur at different types of locales and require responses from a diverse set of public and private organizations as well as the general public. At any particular location, the likelihood of an emergency is remote, but the potential consequences can be severe. The onset of incidents may be sudden and several public and private agencies that do not normally work together may be involved. In past emergencies, local officials have sometimes been unaware of the locations and contents of pipelines, much less how to quickly acquire and transmit relevant information. As a result of these factors, planning responses to pipeline emergencies is difficult, especially regarding who will need what types of information in what time frame.

The Christian Regenhard Center for Emergency Response Studies at John Jay College for Criminal Justice, the City University of New York has received funding from the U.S. Transportation Research Board to "develop a guide for natural gas and hazardous liquid pipeline operators and emergency responders that (1) includes the appropriate emergency response content that should be provided to emergency responders; (2) recommends effective means of disseminating this guidance by pipeline operators to recipient emergency response organizations and by those emergency response organizations to sub-units; and (3) recommends strategies for implementing and exercising the emergency response plan." (Transportation Research Board, 2011) One of the tasks is to "Develop a failure mode and effect analysis of the process for disseminating, exercising, and implementing emergency response plans for natural gas and hazardous liquids pipeline incidents. The analysis should include the roles and responsibilities of both pipeline operators and emergency responders."

Failure modes and effects analysis (FMEA) is a well-established systems safety method. It involves analyzing the ways in which components of a system might fail and anticipating the resulting effects on the function of the system as a whole. Depending on how vital components are to the system, criticality can be assigned and various means can be devised to improve the reliability of the system as a whole. Examples can be adding redundant components or increasing the reliability of components.

To fulfill the requirements of the grant, the project team must first describe a generic emergency communications system that anticipates and responds to pipeline emergencies. The description of an emergency communications system must not be limited to physical components; it is essential to include intangible components such as communications protocols and procedures, rules and regulations, and message content, as well as physical components as such as Geographic Information Systems (GIS) and their associated computer interfaces, global positioning systems (GPS), and voice communications devices. The system description also must not only specify how requirements will vary according to the roles assumed by persons responding to the emergency, but also information is not needed (to avoid overload) and what information needs to be provided by persons in other roles.

We plan to describe a pipeline emergency communications system with both physical and intangible components using a two-step process: (1) a situational awareness information requirements analysis; and, (2) using the results from step one, an information flow analysis. In both cases, we will convene workshops of experts will be used to provide input for the analyses and to review and refine the results.

THE SITUATIONAL AWARENESS INFORMATION REQUIREMENTS ANALYSIS

The situational awareness information requirments analysis (Groner, 2009a) was developed to identify what information is needed by persons in various roles to achieve a sufficient level of situational awareness during emergencies. The approach has been used succesfully to describe informational requirements in two different domains: (1) the use of an elevator system that can be used during fires in high rise buildings (Groner, 2009b); and (2) fire, police and emergency medical service responses to three ambiguous scenarios in high rise buildings (Christian Regenhard Center for Emergency Response Studies, 2011). The three scenarios were a possible fire, a hostile person who may be armed, and possible hazardous materials release of an unknown type).

The approach is similar to the analytic method described by Endsley and her colleagues who recommend a goal-directed cognitive task analysis (Endsley, Bolte, & Jones, 2003). High-level more abstract goals are broken down into increasingly specific objectives and finally into specific decisions. We adapted the approach so that it incorporated the role-specific objectives assumed by emergency responders from a variety of organizations.

The situational awareness information requirements analysis for this study involves using a panel of experts to provide information that will be represented using a goal hierarchy ranked in increasing degrees of specificity. These are: (1) role, (2) goal or strategy, (2) objective or tactics, (3) actionable decision, and (4) required information. The findings can be intuitively represented using a tree structure as shown in Figure 1.

The panel of experts will convene for one or more facilitated workshops where they will be charged with developing information for each of the four levels in the above hierarchy. They can start anywhere in the hierachy. For example, if the group starts with a certain actionable decision, they will be asked to specify the goals that are the reasons why the decision needs to be made, and the types of information that are needed to make the decisions. If the group starts with a type of information that they feel is important, then they will be asked to specify the actionable decision associated with the information. The process will be continued until a comprehensive goal tree is developed where every key role can be linked downwards to the information needed to fulfill that goals, and each type of information can be traced upwards to the role where that information is needed.

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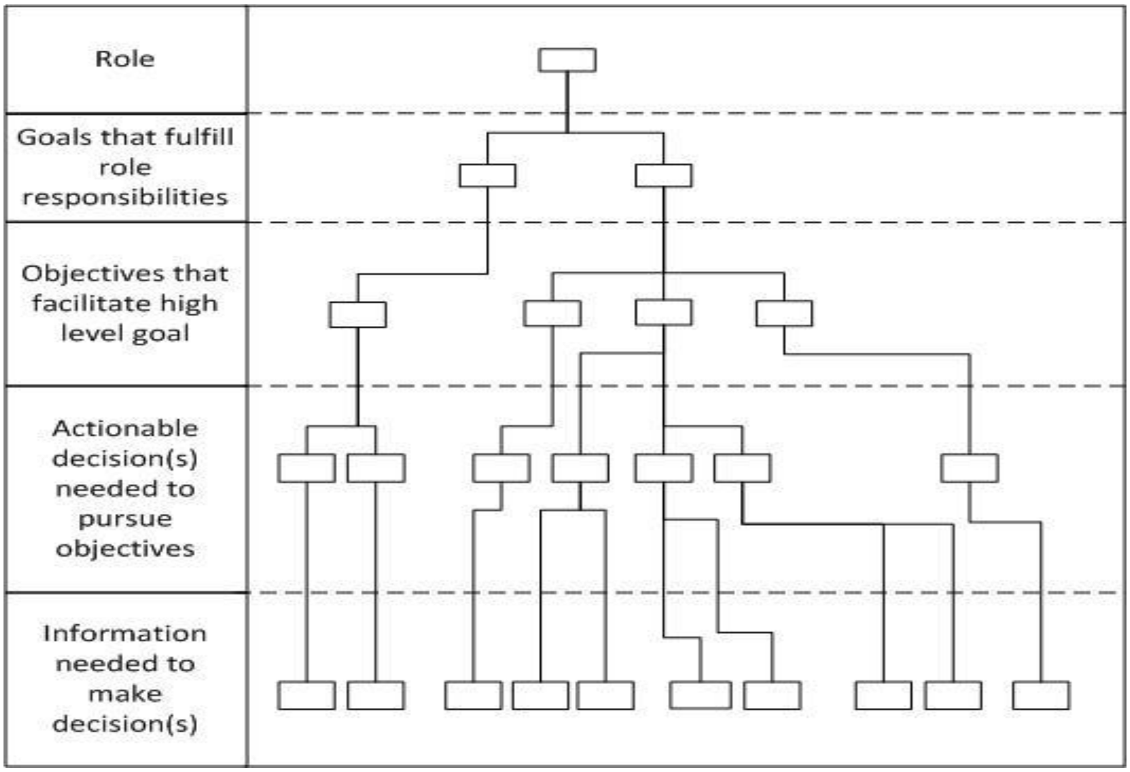

Figure 1. Tree structure for the Situation Awareness Information Requirements Analysis

THE INFORMATION FLOW ANALYSIS

The situational awareness information requirements analysis will yield the information that people in specific roles need to fulfill their responsibilities. However, a subsequent "information flow" analysis is required that will determine the sources of the required information, whether from sensors, computers (e.g., databases and GIS applications) and personal communications from persons in other roles. We will also use the analysis to search for goal conflicts (for example, conflicts between life safety and police investigatory goals) that can inhibit cooperations during emergencies. We hope to graphically represent the findings using an approach after the fashion of Beyer and Hotzblatt's (1998) flow model or task-knowledge-social network analysis suggested by Stanton and his colleagues (Stanton, et al., 2006). An example of a simplified flow analysis is provided in Figure 2.

The same panel of experts used to develop the situational awareness information requirements analysis will also develop the information flow analysis under the facilitated guidance of the project team. The panel will be asked to identify the possible sources for information identified in the information requirements analysis, including both the roles that have and can provide the information and the possible means for relaying the information. They will also be asked to identify potential goal conflicts, that is, reasons why persons who control information might be reluctant to provide the information. Sources of conflict are important to identify because they sometimes interfere with the willingness with which organizations at the local to national levels, both private and public, provide timely and accurate information among themselves.

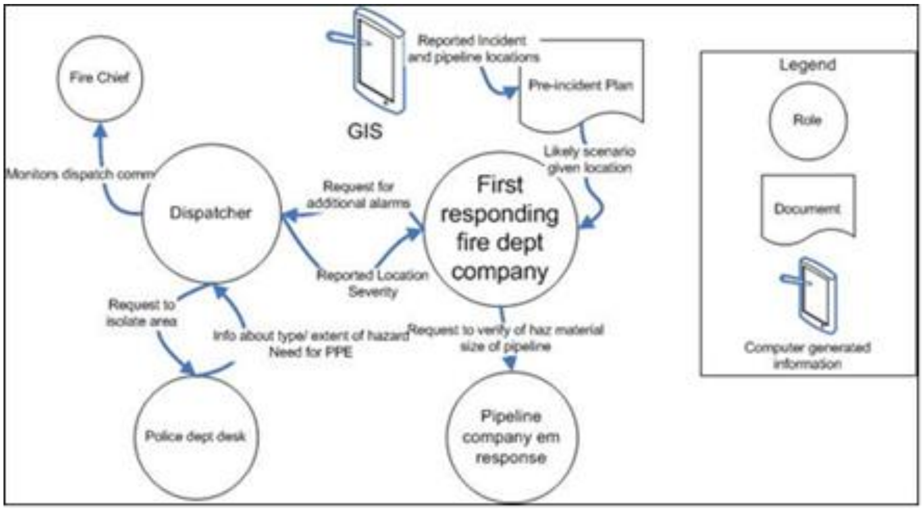

Figure 2. Hypothetical Flow Analysis

THE FAILURE MODES AND EFFECTS ANALYSIS

Once the emergency information system for pipeline emergencies has been described, the results will be analyzed using a failure modes and effects analysis (FMEA). An FMEA is a frequently used systems safety analysis that elicits and compiles judgments about the effects on a system's abilities to meet operational goals when each component of the system is considered to have failed. Judgments about the various modes by which components can fail are specified, along with judgments about how critical each component is to the system's performance. In the context of this project, the system will be the generic emergency communications system developed using the situational awareness information requirements and information flow analyses.

we anticipate that there will be disagreements among experts about the modes of failure and their likely effects on system performance. We plan to use a web-based Delphi group where experts will complete a questionnaire and then interact anonymously to reach consensus. The Delphi approach should help us avoid having individuals unduly influence the results due to their reputations or personalities. We will be requesting the following types of information from participants in the Delphi process: (1) failure modes for each information communications system component identified in the situational awareness information requirements and information flow analyses, (2) estimated probabilities associated with failure modes, (3) the effects on emergency response operations when each component fails, (4) estimated criticality (damage to effective emergency responses) associated with each component failure. To assist in resolving disagreements, participants will be asked to provide rationales for each of the above judgments. The numerical ratings and the associated rationales will be anonymously circulated among the Delphi group members who will then be asked to reconsider their judgments in an attempt to reach consensus.

ANTICIPATED PROJECT OUTCOME

The final deliverable for the project will be a guide to best practices for communications during pipeline emergencies, covering both planning and response phases. Based on the situational awareness requirements analysis and the information flow analysis, the guide will describe the functions and components for an effective information communications system. Based on the failure modes and effects analysis, the guide will base priorities for preparation and response based on the criticality of system components in an effective response to pipeline emergencies. The FMEA is also expected to provide recommendations about how the physical and intangible components of the communications information system can be made more reliable.

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