



Situational awareness for supporting building fire emergency response: Information needs, information sources, and implementation requirements

Nan Li, Zheng Yang, Ali Ghahramani, Burcin Becerik-Gerber*, Lucio Soibelman

Sonny Astani Department of Civil and Environmental Engineering, 3620 S Vermont Ave, Los Angeles, CA 90089, USA

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ABSTRACT

Building fire emergencies are big threats to safety of building occupants and first responders, and they can result in significant property losses. During building fire emergency response operations, establishment and utilization of situational awareness are of essential importance, enabling first responders, especially incident commanders, to better assess changing on-scene situations and make informed decisions. The paper uses an interactive card game to guide first responders to establish situational awareness about an imaginary building fire emergency, and examines the information items needed by first responders in this process. An evaluation of the importance of each information item is performed. The results show that location and status of occupants and first responders, and status and development of fire and smoke are the foremost important information items. Information items in the “at emergency scene” category were updated on average five times more frequently than information items in other categories. In order to investigate sources for obtaining the above information, and examine requirements for better implementing situational awareness at emergency scenes, a nationwide survey was conducted with first responders in the United States. The results point out a discrepancy between current and desired information sources for establishing situational awareness at building fire emergency scenes. The paper also reports detailed implementation requirements, including type of assistance, level of details and format of representation for establishing situational awareness, and illustrates statistical impacts of location, years of experience and job title on the requirements.

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1. Introduction

Building fire emergencies are big threats to the safety of building occupants and first responders. Major fires have revealed that a safe escape from a burning structure is not always possible for everyone [1]. Line-of-duty deaths of first responders can be caused by getting lost, being trapped or disoriented [2]. Public fire departments across the U.S. attended 484,500 fires in buildings in 2011, which caused 2460 deaths and 15,635 injuries [3]. Building fires can also result in significant property losses, adding up to \$9.7 billion or 82.9% of total fire property losses in 2011 [3]. Building fire emergency response, also referred to as interior structure firefighting in OSHA (Occupational Safety and Health Administration) standards [4], is defined as physical activities of fire suppression, rescue or both, inside of buildings or enclosed structures involved in a fire situation beyond the incipient stage. During building fire emergency response operations, establishment and

utilization of situational awareness play a crucial role. *Situational awareness* is a perception of environmental elements with respect to time and/or space, such as locations of occupants and status of fire growth, a comprehension of their meaning, and a projection of their status after some variable has changed. First responders, especially incident commanders, must be skilled in assessing situations based on available information, and taking decisions that make the best use of available resources [5].

However, situations in or around a building during the course of a fire emergency may be chaotic, and may not be entirely transparent to first responders. This issue significantly increases the difficulty for on-site decision making, calling for a well-developed situational awareness [5]. Lack of situational awareness resulting from poor gathering, filtering and understanding of time-dependent information may complicate emergency situations and lead to secondary casualties and property losses [6]. During a building fire emergency response operation, first responders may have fair knowledge of certain aspects, such as routing information and building layouts, which can be obtained from past experience or routine inspections. However, all aspects of situational awareness cannot be obtained beforehand. Various information items, such as

* Corresponding author. Tel.: +1 213 740 4383; fax: +1 213 744 1426.
E-mail address: becerik@usc.edu (B. Becerik-Gerber).

location of trapped occupants and growth of fire, are dynamically generated in the course of a fire emergency and therefore have to be obtained and updated on site from various information sources. Human factors play a critical role in the development of situational awareness. For instance, prior research found that attention and working memory are critical factors limiting people from acquiring and interpreting information from the environment to form situational awareness [7]. The situation awareness-supported decision-making process usually begins with matching an integrated picture of the current situation to prototypical situations in human memory, followed by matching the prototypical situation to a certain action or decision predefined in memory or by experience [8–10]. Consequently, information needs and difficulties in accessing them are further increased during mutual aid operations. The reason is, when first responders are dispatched to building fire emergencies that occur outside their jurisdictions, they may find their memories and experience inappropriate or inadequate, and find themselves in need for a large amount of information including the most basics, such as routing maps and weather forecasts. Moreover, upon establishment of situational awareness, first responders may have various requirements for better implementing it, including information collection, analysis and representation. Meeting such requirements at emergency scenes require non-trivial efforts. Yet, if achieved, situational awareness enables first responders to comprehend on-scene situations in a faster and more accurate manner, and to make more informed lifesaving decisions.

As a first step for supporting building fire emergency response operations with improved situational awareness, this paper evaluates the information needs by first responders to establish on-scene situational awareness. The paper then identifies sources for obtaining the needed information, and examines requirements for better implementing situational awareness at emergency scenes. The rest of the paper is organized as follows. Section 2 reviews procedures of building fire emergency response operations. Section 3 reviews prior research about situational awareness in the context of building fire emergency response operations, and outlines the objectives of this paper. Section 4 evaluates the information needs of first responders, followed by Section 5 that examines information sources and implementation requirements of on-scene situational awareness. Section 6 discusses the findings, and Section 7 concludes the paper.

2. Building fire emergency response operations

Procedures of building fire emergency response operations are generally the same in different countries [11]. Taking the United States as an example, when responding to building fire emergencies, fire departments are the first line of defense. Upon the receipt of a 911 emergency call reporting a building fire, a 911-dispatch center initializes an emergency response operation. A dispatch system automatically alerts standing-by local fire stations based on pre-determined assignment plans. Local fire stations are usually composed of paramedic teams and fire companies including truck companies and engine companies. Engine companies are equipped with hoses and water so that personnel can aggressively fight the fire. Truck companies are like a firefighter's toolbox, carrying ladders, rescue equipment and other tools to enable personnel to support firefighting activities. Type and amount of resources dispatched to a building fire emergency is based upon type and size of the building and severity of the emergency incident.

Local fire stations alerted by a dispatch center are assigned a run sheet, which shows basic information of an emergency incident, including emergency type, time, address, and dispatched responding units. The first captain arriving at an emergency scene

is usually assigned as an incident commander, and the role is later transfer to higher-ranking on-scene officers.

The first duty upon arrival at an emergency scene is to "size up" or make a quick appraisal of situations and determine actions to be taken. The following aspects must be assessed during a size up [12]: (a) life hazards involved or rescue work required, if any; (b) exposure hazards from both interior and exterior viewpoints; (c) type of building construction; (d) content hazards to both occupants and first responders; (e) accessibility of fire; and (f) type and amount of fire equipment required.

After a size up, the incident commander assigns standing-by first responders to a number of tasks. These tasks are repeatedly performed by shifting units of first responders until the situation is completely under control. These tasks include [12]: (a) *Search and rescue*. It is an operation taken to recover trapped occupants from situations that prohibit their escape. Searching for occupants is done in two rounds. A primary search is done at the beginning of a response operation to quickly locate and rescue occupants in danger. A secondary search is done, when the situation is under control, to locate trapped occupants not rescued in the primary search. In both rounds, first responders need to check all of the spaces in a building, and they mainly rely on sight, sound, and touch to discover trapped occupants [13]. (b) *Fire attack*. It is an operation taken to retard or reduce the rate of burning, with an ultimate objective to extinguish the fire. If a building is completely engulfed in flames, fire and heat have to be reduced before search and rescue is possible. Fire attack is usually done with three methods, namely cooling or reducing temperature below the ignition point, smothering or reducing oxygen content within fire area below burnable limits, and removing fuel from vicinity of fire. Water is the principal fire-extinguishing agent for fire attacks, and certain water pressure and water volume in gallons per minute depending on the type and size of the building have to be ensured. (c) *Ventilation*. It is an operation taken to remove smoke, gases and heat from a burning building, and to control fresh air supplies to aid fire attack and search and rescue. There are two ways of performing ventilation, namely vertical ventilation and cross ventilation. The former is done by making exit openings for smoke, gases and heat on roof, while the latter is done floor by floor, by utilizing outside openings such as windows. (d) *Salvage and overhaul*. It is an operation taken to prevent excessive water damages, and reassure against any possible re-ignition of fire. It is done after fire is put out and trapped occupants are rescued. Salvage involves protecting materials with salvage covers, absorbing excessive water, and directing water outside. Overhaul involves inspecting concealed spaces, where fire may continue to burn unnoticed, and removing glowing or burned materials. (e) *First aid*. It is immediate and temporary care given to casualties before professional medical personnel can treat them. First responders need to deal with the following types of injury: bleeding, respiratory deficiencies, shock, fractures, burns, and wounds. (f) *Fire investigation*. It is the last step taken at a scene. It involves determining fire origins, identifying fire causes, and estimating losses. If there is suspicion of arson, evidence should be preserved. This paper focuses on search and rescue, fire attack and ventilation stages, from when first responders are dispatched to when fires are suppressed and occupants are rescued.

3. Related work and motivations

Endsley [7] proposed the most widely recognized model of situational awareness. In this model, situational awareness consists of three hierarchical levels, namely the perception of the status, attributes, and dynamics of relevant elements in the environment (level 1), the comprehension of the significance of

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