Modelling Information Flow and Situational Awareness in Wild Fire Response Operations

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Abstract. Wild fire management is often an intense and highly dynamic context, which requires the continuous flow of large amounts of information. It requires effective preparedness, quick response, and efficient and effective team communication and situational awareness. Aside from the skills and experience of the management team, the success of the process often depends on effective tools and technology that can present, communicate, and document the fire information in a way that supports and facilitates the response process. The aim of this study was to assess the informational needs of the wild fire response process and model the information flow and situational awareness, with and without supporting technology. It aimed to translate the findings to definitions and requirements for enhancing the process through human-computer interaction (HCI) design solutions and improved usability.

Keywords: Situational awareness · Emergency response · User-centered design · Wildfire response · Process analysis · Design requirements

1 Introduction

Forest fire management is the process of planning, preventing and fighting forest fires to protect people, property and the forest resource. The primary goal of the Ontario wildfire management program is the protection of public safety and values. This can only be achieved through quick and efficient information communication and response operations. However, the wildfire response process includes the processing of large amounts of information collected from a complex and constantly changing situation. In addition, response operations are often conducted by distributed teams, which can result in challenges and breakdowns in communication.

This study provides detailed insight about the response process and requirements. It focuses on the information flow between the field and the headquarters offices. The information flow includes the collection, communication and distribution of fire information required to maintain an accurate representation of the situation and awareness about its dynamic factors. In addition, the study highlights pain points in the current process that can be explored in future research. These pain points are current obstacles or problems that slow the process down or result in information loss. The aim of this study was to assess the informational needs of the wild fire response process and model the information flow and situational awareness, with and without supporting technology.

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2 Literature Review

This research focuses on the communication and flow of information that is required to maintain situation awareness and to conduct response operations in emergency management.

2.1 Emergency Response

Forest fires are considered emergency incidents that require a special emergency response process to manage[1]. The management of an emergency response process requires a high level of complex coordination between different operators and locations, in addition to efficient and timely communication. One of the many challenges of the domain is the necessity for rapid decision-making in situations of uncertainty and under time and resource constraints [1]. The establishment and maintenance of situational awareness (SA) is an essential requirement for successful crisis and emergency management [2]. The maintenance of SA requires the proper collection of complete and accurate information about the situation in an accessible and timely manner as well as the proper analysis and interpretation of the different factors and overall situation [3].

Effective communication and information flow is identified as one of the key components of an effective incident command system [4, 5]. Teams often have to function in fast-paced, large-scale and stressful events where members are required to deal with and process large amounts of ambiguous information that must be processed in a limited time [5, 6].

2.2 Situational Awareness (SA)

As described, the process of emergency response requires all members of the response team to be on the same level of awareness about the factors affecting their strategy and decisions; also known as situational awareness (SA).

One of the most popular theoretical models of SA and its role in the dynamics of human decision making is the one developed by Endsley [7]. According to the model, SA must go beyond the perception of the elements in their environment to the interpretation of all factors and prediction of their development in the near future. Endsley explains that, in addition to the goals and objective, this three-step process is affected by several other factors [7]; these include a person's knowledge and experiences, their working environment as well as the interface and system that they are working with.

Mica Endsley's SA model is most widely used in the reviewed literature and was therefore the guiding model in this study. However other definitions and models of SA

[1] Emergency Management Ontario.

include having a "common operational picture" [8] and a "moment to moment knowledge about, and understanding of the […] environment" [9].

Emergency response is always conducted by teams. This can add even more complexity to the required SA; in addition to the awareness about the environment, the operators are required to be updated with other team members' activities, status as well as contribution to the cooperative task, also refereed to as Team Situation Awareness (TSA) [10]. The information is required to be continuously extracted from the dynamic situation and integrated into the team's awareness model and situation representation upon which decisions are taken [11]. The study confirms the importance of continuous acquisition and update of information for the maintenance of TSA.

3 Methodology

The study took place in the province of Ontario, Canada, with the Ministry of Natural Resources and Forestry (MNRF) as the responsible provincial ministry. In-Situ research was conducted in three forest fire response and management offices: the regional and sector headquarters in Dryden and Sudbury, and the provincial office in Sault Ste Marie.

The qualitative research methods used in this study were the observation of the daily workflow including preparedness and response processes, interviewing response operators and the attendance of a fire response simulation training session.

3.1 Interviews

The interviews were semi-structured, and focused on understanding the individual responsibilities, needs and priorities of the different team members, as well as understanding their perceived and actual role within the overall response process.

All the interviewed operators have worked at the response offices during fire seasons, with their experience at the ministry ranging from 6 to 33 years. The interviewed operators also occupied different roles within the response team in order to gain insight from different perspectives; they included duty officers (DO), aircraft management officers (AMO), fire intelligent officers sector response officers (SRO), as well as radio operators, crew leaders, pilots and technical employees.

3.2 Fire Response Training Simulation

In addition, a crew leader training simulation was arranged at the Dryden Sector office, in order to observe the communication and process required during a response operation. The simulation was video-recorded and the researcher received the script of the simulation as well as a fire diary to follow the procedure. Several other MNRF report documents and training handbooks were also collected in order to understand the requirements of the process.

3.3 Analysis Verification Methodology

To ensure the accuracy of the process analysis, a document that summarized the most important process analysis insights was created and sent to ten operators from the three locations for verification. The document used for the verification included a description of the purpose of the study and of the analysis, and the results of the study, described in the next section.

4 Results

The observations focused on understanding the physical environment as well as the work dynamics of the team members. In the interviews, the operators described the daily work process from the perspective of their role within the team and the tools and software that they use to complete their tasks.

In all of the visited offices, the desks of the operators were generally arranged so that operators can easily communicate together while still able to see the common screen. Radio operators were situated in adjacent rooms with glass separation.

4.1 Technologies and Communication

The study showed that the response process utilizes a variety of tools of different technological levels to allow the team members to get a comprehensive overview of the situation in the region or sector. Information and databases required are accessed through the Fire Management Information System (FMIS). FMIS gives access to the Daily Fire Operating Support System (DFOSS), area information database and aircraft (Mapper) and personnel. Figure 1 presents the information flow and communication channels between response teams as well as the operators involved on each level.

4.2 Information Categories

The tools used to communicate information can be categorically divided into individual workstations and shared displays. The shared tools include displays for weather forecasts, and regional maps showing resource locations. Operators also have access to the information and tools through their own workstation.

Figure 2 shows a model of the three main components of the information communication process and their sources: 1. The incoming information (top box); 2 The tasks and decisions it supports (left box); and 3. The sources for the shared SA. Further analysis of the information was conducted to identify information categories, based on the study as well as previous research [3]. The categorization was done through an affinity diagram (Fig. 3) that sorted the information in the response and process specific categories as well as prioritized the different elements.

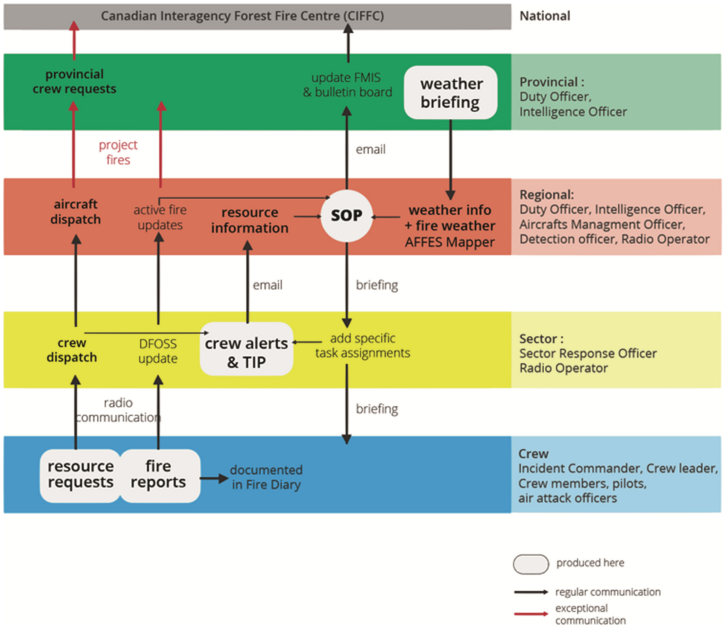

Fig. 1. Vertical communication between response teams (Color figure online)

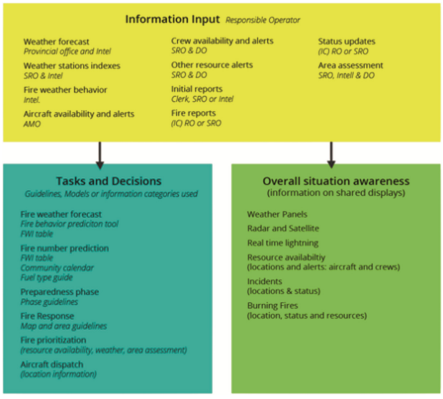

Fig. 2. Overview of information components and flow

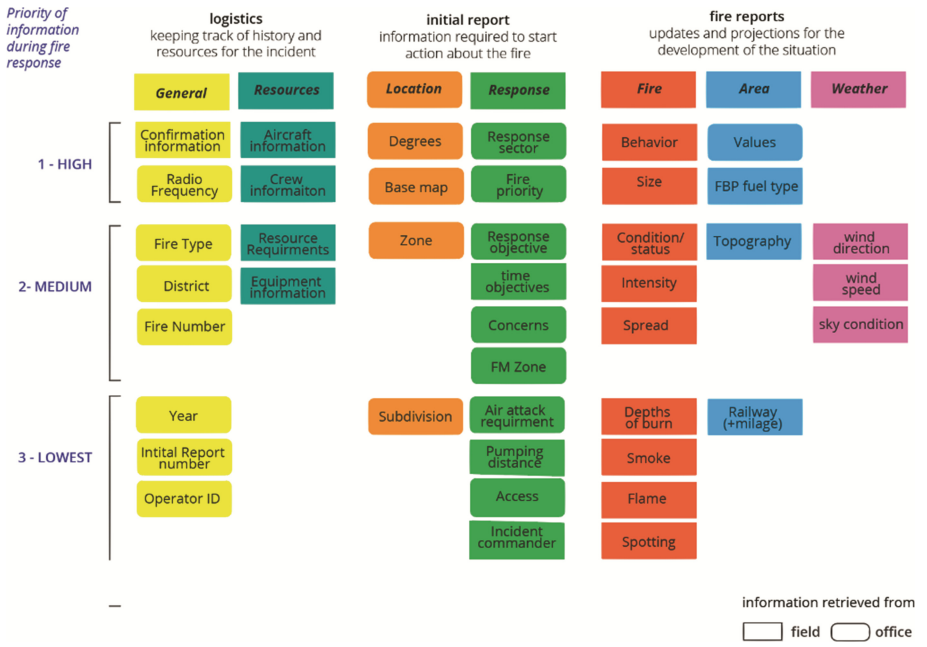

Fig. 3. Final affinity diagram showing categories and prioritization

4.3 Information Requirements Analysis

In the next steps of the analysis, the information required for response processes were analyzed for specific operators. For this analysis, decision ladders for four of the main operators were created. These are diagrams that summarize the information processing and cognitive steps as well as the information required for completing the step [12] (Fig. 4).

4.4 Pain Points and Challenges

The analysis of the process showed that operators' tasks and decisions are highly interdependent and heavily rely on timely and accurate communication of information. Several challenges that could cause delays or miscommunications in the process were identified:

(1) Reliance on verbal and radio communication
Despite the availability of technologies to keep a good level of situational awareness within the team, a major reliance on verbal communication was noted. This challenge is especially critical in communication between the crew in the field and the offices where radio communication is the only available channel to communicate information.

(2) Retrieval of information from different sources
Operators have to search for the required information to complete their tasks and make timely response decisions among different sources and displays.

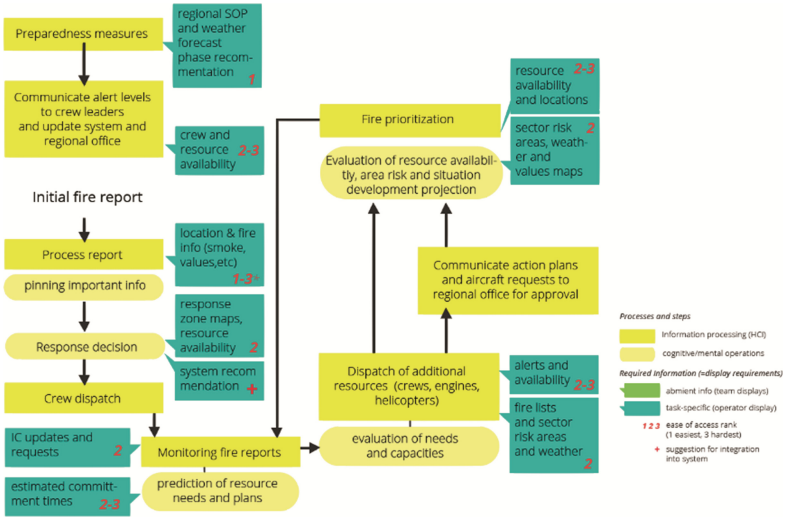

Fig. 4. The verified decision ladder for a sector response officer (Color figure online)

(3) Manual documentation of information
Incident information is manually recorded in the Fire diary by the incident commander. Additionally, each office operator is responsible for manually logging actions and events.

4.5 Enhancement Proposals

The above-described analysis concluded that the existing challenges could be addressed through facilitating the interaction with existing tools and databases rather than radical changes in the process. Based on this analysis, the following high-level system enhancements were proposed:

(1) Facilitate information collection, communication and documentation:
Improved usability and efficient interaction with the software can enhance the speed and the quality of the information inputted into the system as well as reduce the operators' reluctance to use them for communicating information. System enhancements should also integrate automatic documentation tools and logging of updates and incident developments. Such tools would be used for after-action reviews and process assessment.
(2) Interface design that supports team situation awareness:
The design should accommodate team communication through document sharing, messaging or conference call tools. The interface should also provide information about team members' activities [13], location and task assignment and progress according to process requirements.

(3) Operator- specific or customizable dashboard:
Dashboard designed to accommodate operators' specific needs. It would serve as operator-specific hubs for collecting information with shortcuts to frequently used software and databases It should also support the interaction between team and operator displays without interrupting their specific tasks through integrated notification and alert system [14].

5 Conclusion and Future Research

The study highlights the significance of effective and efficient information collection, from a variety of sources and through various technologies. This can impact effective shared situational awareness, not only within the response office, but also with the remote and dispersed ground crews.

The analysis of the response process led to user- and process-driven design proposals that can address the pain points of the process as well as the challenges of situational awareness. The proposed system enhancements aim to guide integrated process oriented and user-friendly designs that can be developed to make the response process more efficient and usable. The information categorization and the requirements analysis could also guide the organization of the design and interfaces of the system.

Furthermore, the study provides detailed insight about the response process requirements, and the analysis and verification of the communication and information flow needed for maintaining SA and completing wildfire response tasks. The results could therefore be used and explored for further forest fire management research.

The analysis methods can also be applied to other command and control and emergency response context like medical emergencies, military operations or other response processes. The findings and conclusions can also be extended to other context where information collection, communication and documentation are critical to mission success.

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