Developing an Optimized UI for Traffic Incident Managers

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Traffic Incident Managers (TIMs) coordinate first responders and help resolve traffic-related incidents. Currently, some use over fifteen different software applications with unique functionalities across three monitors to manage incidents, leading to redundant data entry, unnecessary task switching, and delayed responses. 40 hours of TIMs' screens were recorded during their normal work hours at the Iowa Department of Transportation (DoT). The resulting task analysis from these videos greatly influenced the design of a simplified, web-based, user interface (UI) prototype. The new UI offers a 42.9% reduction in the steps required to manage an incident by combining the functionality of the fifteen different applications used in the existing system into a single, structured UI. This research approach offers a UI model to other DoTs that can lead to faster and more effective incident management.

INTRODUCTION

Many people who use computers as an integral tool in their workplace find themselves operating a variety of applications, each with their own functions. Switching between these applications often requires operators to maneuver between inconsistent UIs with different design structures, metaphors, and layouts. The disconnect between the users' task needs and the available software creates usability challenges which can lead to errors and decreased productivity (Nielsen, 1999).

Traffic Incident Managers (TIMs) often face these issues when monitoring and managing traffic incidents to minimize their impact on traffic flow. TIMs, performing multiple tasks simultaneously, monitor a variety of data streams and quickly adapt and respond to constantly changing incident conditions. These tasks include managing on-scene personnel, deploying traffic management plans, and active communication with citizens and government agencies across several platforms (Carson, 2010). Additionally, TIMs must carry out their tasks in an assortment of disjointed software applications with varying user interfaces (Choi, Taib, Shi, & Chen, 2007). This paper outlines the development of an improved user interface that will decrease TIMs' incident processing time.

Effective traffic management in the United States is becoming increasingly important. In 2014, congestion in urban areas forced drivers to travel nearly seven billion additional hours, with a total congestion cost of $160 billion (Schrank, Eisele, Lomax, & Bak, 2015).

The following section describes the tasks TIMs perform. Related research and its influence on design choices are then discussed followed by an outline of the methods for creating the new UI and its preliminary evaluation.

TRAFFIC INCIDENT MANAGEMENT

Traffic Management Centers (TMCs are the central hub for monitoring and managing traffic (Jin, Zhang, & Gan, 2014). They are operated by TIMs, who monitor roadways and road sensor data while scanning for obstructions to the flow of traffic, such as stalled vehicles, wrecks, and debris. TIMs' work is highly collaborative and frequently requires in-house

and external communications. Communications are performed via radio, email, in person, and by phone. Currently, there is research on improvements to the methodology of TIMs through training processes (Owens et al., 2012). However, with an average of 110 traffic incidents a day at the local DoT (*Performance (May): Traffic Managment Center*, 2017), there is a need for a program that allows TIMs to quickly and successfully clear incidents by facilitating communication and multitasking in a unified UI.

To maintain normal traffic flow, TIMs follow five main steps. These steps include detecting and verifying an incident, relaying traveler information, responding to the incident, managing traffic response and appropriate personnel on scene, and incident clearance (Carson, 2010) (Figure 1). Motorists and crash victims are safer and traffic congestion decreases if TIMs effectively and quickly clear traffic incidents from roadways (Ogle, Chowdhury, Huynh, Davis, & Xie, 2017).

Incident detection identifies the type and location of a traffic incident by bystanders, traffic personnel, or artificial intelligence (Carson, 2010). Many problems, such as receiving incorrect information from the scene or overloading TIMs through repeated contact from witnesses, can arise in this stage (Ogle et al., 2017).

Next, the public is informed of traffic incidents to minimize traffic congestion (Ogle et al., 2017). Often incident information is relayed through Dynamic Message Signs (DMSs) which are electronic signs installed along most highways, and traveler information systems, such as Iowa 511 which is a public traveler information website and hotline. Traveler information is often manually activated by TIMs and, if incorrectly recorded, can cause difficulties and further traffic delays (Carson, 2010; Ogle et al., 2017).

Response to an incident involves sending resources, such as highway helpers, tow trucks, or emergency medical services, to the incident (Carson, 2010). Issues may arise at this stage if response time is too slow or if excess or insufficient resources are deployed (Ogle et al., 2017).

The fourth step is the management of traffic and the scene. Once highway helpers and first responders have arrived on the scene, the incident can be managed accordingly (Ogle et al., 2017). Issues tend to arise when there is ambiguity in leadership, roles, or a response plan (Ogle et al., 2017).

Incident clearance begins when authorities confirm the incident has been cleared from the roadway. It involves returning roadways to their set standards, clearing DMSs, and updating traveler information systems (Ogle et al., 2017).
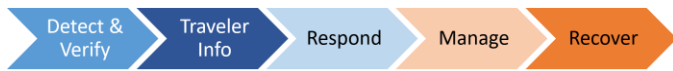
Figure 1 The five main steps of traffic incident management, based on (Carson, 2010).

RELATED LITERATURE

Multiple Monitors

TIMs at the Iowa DoT use a three-monitor configuration on their desktop. Due to this arrangement, the effectiveness of multiple monitors in relation to multitasking was researched. Multiple monitor setups, both for two and three-monitors, have been found to provide greater usability than single monitor displays (Colvin, Tobler, & Anderson, 2004; Truemper et al., 2008). The use of multiple monitors also has been found to facilitate more effective multitasking due to the natural partitioning that occurs when using multiple monitors (Truemper et al., 2008). Through a field study, Grudin (2001) found users tend to apply different tasks, categorized as primary or secondary tasks, to separate screens. For this reason, the prototype UI was designed to divide the duties of a TIM into three parts. These parts were then divided by monitor as suggested by Grudin (2001).

Multitasking

The definition of multitasking as switching between multiple tasks simultaneously was applied to this research (Johnson, May, & Johnson, 2003). Multitasking has been demonstrated to be routine in most workplaces (KC, 2014), and many believe this is the best way to complete work in a timely manner. However, research has shown that multitasking has negative effects on job performance (Monsell, 2003; O'Conaill & Frohlich, 1995; Rogers & Monsell, 1995; Rubinstein, Meyer, & Evans, 2001), learning (Foerde, Knowlton, & Poldrack, 2006), attention deficit trait (Hallowell, 2005), productivity (Aral, Brynjolfsson, & Van Alstyne, 2007), and stress (Sum & Ho, 2015). Although multitasking has negative effects on job performance, the nature of work done by TIMs requires some tasks to be done in parallel (e.g., filling out reports while monitoring an incident). Though multitasking cannot be eliminated, it can be presented in a more effective manner (Otto, Wahl, Lefort, & Frei, 2012). To allow for effective multitasking, the tasks currently requiring high workload, such as filling out reports which require visual, cognitive, and psychomotor functions, were simplified in the new UI.

METHODS

TIMs at the Iowa DoT Traffic Management Center (TMC) use over fifteen different applications to identify, report, and manage traffic incidents. This section describes the observation method, task analysis, and prototype development.

Observations

Video and audio recordings of TIMs' computers and microphones served as the basis for identifying system requirements. These recordings were completed with OBS Studio (obsproject.com). Screen recordings were utilized for two reasons. First, external cameras are unable to adequately capture TIMs' screens due to glare and other lighting factors. Second, since the TMC is a government facility, restricting recording to just the participants' screens lessened the likelihood of recording confidential information. OBS Studio recorded everything displayed on the participants' screens, as well as any audio that passed through their computers. However, TIMs had complete control over when their computers were being recorded and were free to start and stop recording at any time. A behavioral codebook developed and outlined by Monaghan et al. (2018) was used to analyze the procedures of TIMs. This analysis assisted in the abstraction and refinement of tasks performed by TIMs.

Task Analysis

A previous hierarchical task description (HTD) of the TIMs showed all the tasks TIMs must perform in each traffic management stage and the steps and timings necessary to complete each of those tasks (Monaghan et al., 2018). The HTD allowed the authors to compare steps required for the current system with those for the new UI. Additionally, the HTD was abstracted into goals, rather than tasks, and turned into a hierarchical tasks analysis. The hierarchical task analysis lists the necessary goals without describing how these goals would physically be completed. This HTA was used to ensure that all system requirements were met with the new UI.

Prototyping

The principles of agile design were used to design the UI prototype (Gunasekaran, 1998). Once or twice a week, a new prototype was created; seven separate iterations were completed in total. The early designs were paper prototypes which were fine-tuned to ensure the new UI could functionally replace the current UI. After the paper prototypes were finalized, a digital prototype was created.

RESULTS

Observations

Across four TIM participants, over 40 hours of audio and screen recordings of their daily work were behaviorally coded. Of this footage, 32.5 hours of general work behavior (i.e., incident management as well as other TIM duties) were analyzed, and 7.5 hours of strictly incident management footage were analyzed. Through behavioral coding, the authors were able to identify tasks to improve. TIMs were observed to spend a large portion of their time on their reports. However, since TIMs complete various forms based on the incident type and severity, some information must be entered multiple times manually. These different reports are also

accessed through different applications, which requires screen switching and, consequently, time.

Hierarchical Task Analysis

The HTD, divided by stages in Figure 2 through Figure 5, displays the exact tasks and steps necessary to complete each stage of the traffic management process in the existing system. This HTD revealed several inefficient processes, many of which were linked to switching between applications and/or redundant data entry.
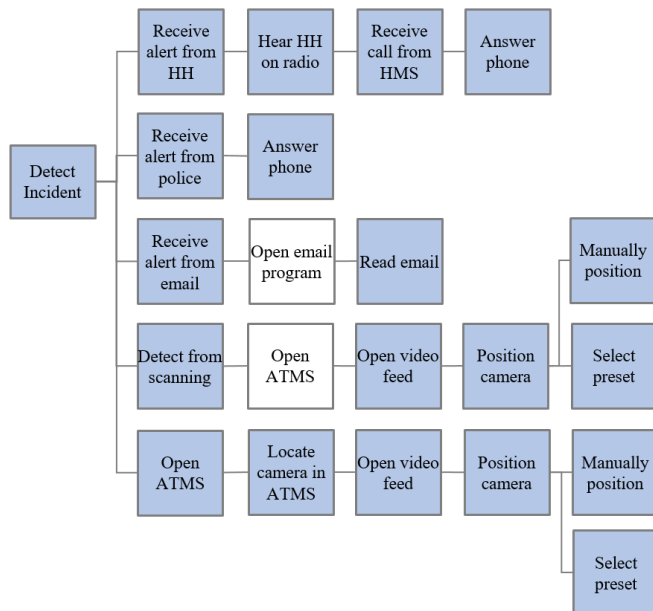

Figure 2 Incident detection and **verification; eliminated tasks in white.**

As noted through observations, and then confirmed through the hierarchical task analysis, changing the reporting system offers major potential for step reduction. TIMs must fill out a variety of reports through various applications for each traffic incident. The new UI combined the reports allowing TIMs to enter information only once in a single form.

Additionally, multiple map applications, each with unique functions, are used by TIMs. This requires switching between applications to retrieve different information. For example, one map application used identifies the locations of highway helpers while another map application provides access to traffic cameras. Typically, to manage an incident, a TIM must navigate between maps to verify the incident through camera feeds and then to determine the nearest highway helper. In the new UI, layers were utilized on a single central map. These layers provide TIMs with all of the information the original map applications provided but without having to change screens.

Comparing the HTD of the existing system with the prototype, a significant decrease in tasks required to complete the same goals is noted. Figure 2 through Figure 5 display eliminated tasks for the new UI in the lighter shaded task boxes. The different traffic incident management stages, detection/verification, response, management, and clearance show step reductions of 9.5%, 47.5%, 55.3%, and 36.4% respectively. The number of steps necessary to manage an

incident, from detection to clearance, was reduced from a total of 119 steps to 68: a 42.9% reduction.
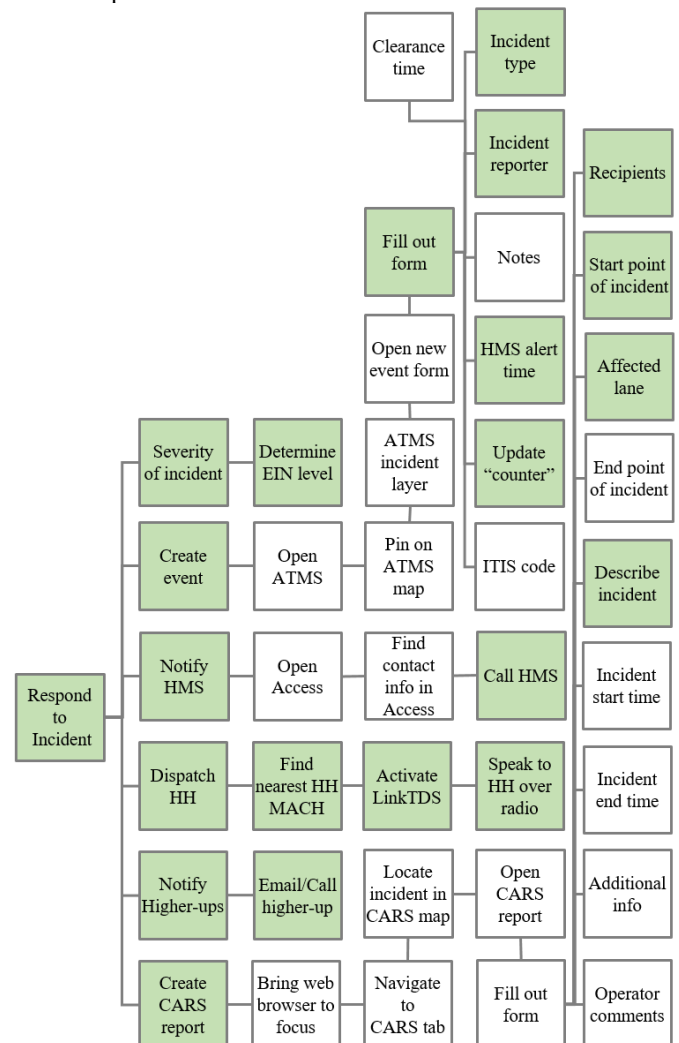
Figure 3 Incident response; eliminated tasks in white.

Prototyping

TIMs' computer-based tasks are divided into three categories: cameras, map, and communication. In the designed prototype, tasks were divided so one task was devoted to each of the three monitors. The left screen contains anything pertaining to the TIMs' traffic cameras such as camera views and view controllers as seen in Figure 6. The center screen, in Figure 7, displays the map of the roads along with its overlays (such as traffic congestion and DMSs) as well as incident tickets for each incident detected. The right screen holds communication features such as email, reports, and highway helper communication as seen in Figure 8. This division of tasks is intended to enhance the usability of the UI on multiple monitors and minimize multitasking.

To further increase the usability of the UI, there was special attention to color. Widespread use of saturated color was avoided, except for cases of drawing attention to specific UI elements such as an alert (Watzman, 2002). A 2011 study showed participants judge blue as the most and black as the least trustworthy colors (Alberts & van der Geest, 2011).

Since TIMs' trust in the UI is vital to efficient and effective clearance of traffic incidents, blue was utilized throughout the interface. A saturated red was used only for incident alerts.
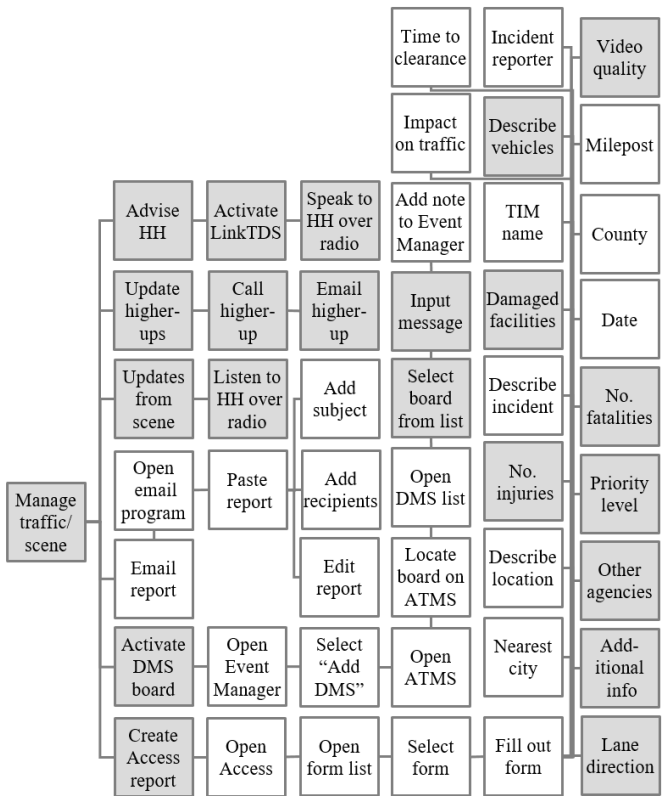

Figure 4. Incident management HTD with eliminated tasks in white.

When an alert is acknowledged it turns from red to blue to maintain the overall trustworthy look and feel of the interface. This change in color for new alerts once they are acknowledged is an example of color coding, which has been found to benefit the utility and usability of a UI and, overall, reduce the number of clicks to complete a task (Brown, Burbano, Minski, & Cruz, 2002; Ferris & Zhang, 2016). An example of the color usage in the new UI can be seen in Figure 7.
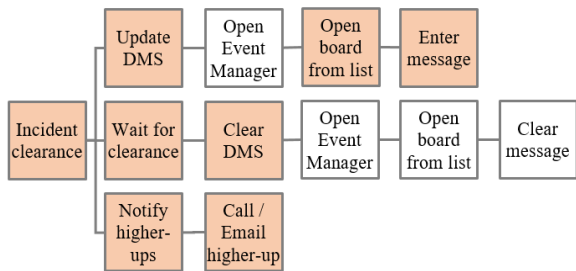

Figure 5. Incident Clearance HTD with eliminated tasks in white.

Additionally, the authors aimed to meet the ISO 9241 standards of usability by creating the user interface based on a hierarchical task analysis of the TIM's tasks. Since detection is the first step to incident management, the applications required for detection, such as cameras, highway helper radio

communication, and email access, were made readily available to users. The hierarchical task analysis also demonstrated the steady utilization of the mapping applications for actions such as pinning incident locations and accessing DMS boards. Often information from the mapping applications was referenced in the reports. By centralizing the new UI's map section on the central monitor, the authors addressed these tendencies and provided users with direct and easy access to the mapping application.

Typography rules were also taken into consideration. Sans serif typefaces have been found to be both faster and easier to comprehend than serif typefaces on digital displays (Dogusoy, Cicek, & Cagiltay, 2016). For this reason, sans-serif fonts were incorporated throughout the UI prototype to improve TIMs' performance and efficiency.

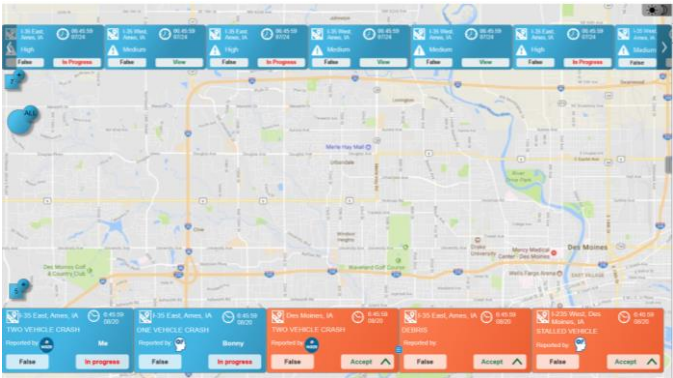**Figure 6: Camera and Video Monitoring Monitor One.**
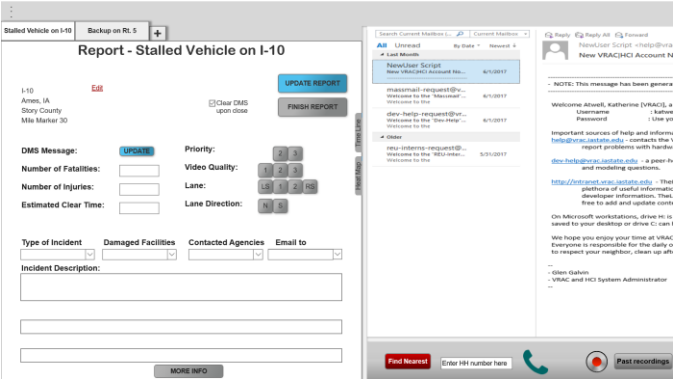

Figure 7: Mapping UI design.

Figure 8: Right Monitor Designated for Communication.

DISCUSSION

Working with multiple software applications in the workplace often leads to excessive task-switching and a high mental workload (Monsell, 2003). TIMs face challenges, such as constant screen switching, that hinder their effectiveness when using a patchwork of applications not designed to work together. Reducing this cognitive workload through the development of a single unified user interface has the potential to increase the TIMs' efficiency by reducing the number of steps to report an incident while decreasing their response time. The authors believe the proposed UIs, which reduces the steps needed to complete an incident management task by 42.9% in the task step comparison, will reduce cognitive workload.

While the task analysis reveals an advantage for the new UI, it still requires usability testing with TIMs. The authors plan to validate the task analysis with usability tests on TIMs at the Iowa DoT as well as with other state departments of transportation. The prototype's modular, web-based approach should allow the new UI to flexibly meet the needs of other TMCs but refinements will likely be necessary.

In the future, the authors plan to develop a higher-fidelity prototype that can be used with real-time incident data within the TMC, surrounded by the multiple communication channels.

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