# Testing the Usability of a Decision Support System for Increasing Environmental Awareness

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***Abstract*— Military facility managers must track repeated contaminant release that occurs from scheduled training exercises to mitigate the effects of those releases before negative effects occur. Training facility managers are tasked with analyzing the accrual of contamination to their facility grounds, understanding the potential for contaminant transport, and planning future mitigation to remove documented contamination. To provide greater awareness to facility managers of the complex contaminant behavior and effects to the environment, we have developed a decision support system (DSS) that assists facility managers with both tracking the environment quality and contaminant accrual and allows them to select proper mitigation exercises. During the design phase of our DSS, we conducted a usability test to identify breakdowns within the DSS's design and workflow to direct the future design and capabilities of the application. Our informal usability test consisted of creating a hypothetical use-case backed by a realistic scenario, tasks for our participants to complete, and implementing our static design mockups into an interactive, high-fidelity prototyping environment to simulate the intended functionality of the software. Participants consisted of a mixture of internal company employees including several software usability experts. The results of our usability test showed a mixture of low-level and high-level opportunities for design enhancements regarding the layout and organization of information included within individual tools and capabilities. We have made revisions on the design and plan to conduct additional usability tests with active duty and/or civilian facility managers to further enhance the usability and usefulness of this DSS application.**

***Keywords— environmental awareness; decision support system; usability testing; workflow support; visualizations***

## I. Introduction

In military training facilities, an important task for facility managers is tracking the state of the environment leading up to and following the execution of training exercises. An influx of toxic chemicals (e.g., resulting from infantry training exercises) that are not properly tracked, contained, or removed from training facility grounds increases the chance for events to occur with potentially significant and severe consequences for the local ecosystem, such as contamination to resident groundwater sources or an increased threat to endangered wildlife living in the local region. To prevent such events from occurring, military training facility managers are tasked with understanding when it is necessary to schedule proper mitigation events (e.g., soil removal, or the installation of preventative barriers) and balance the scheduling of these events with existing training schedules. The awareness of what types of mitigation are appropriate (e.g., soil removal versus installing more vegetation, or performing bioremediation) and when to schedule mitigation is difficult for non-environmental science experts, such as facility managers. This awareness requires at least an operational knowledge of complex environmental behaviors and effects (e.g., contaminant transport rates [1]). To assist military training facility managers with analyzing environmental behavior and contamination effects and selecting proper preventative strategies and mitigation exercises for contaminant removal, we have developed a decision support system (DSS), termed CLEANSE, to increase their awareness of the facility's environmental status.

During the design process of CLEANSE, we conducted a Work Domain Analysis (WDA) by speaking with training facility range controllers and environmental specialists to identify important end-user task and information needs and hypothesized the best way to deliver these needs to facility managers. These needs included intuitive and accessible (to non-environmental science experts) presentation of required information of contaminant properties and mitigation techniques, intuitive representation of contaminant accrued volumes and transport rates, and functionality that needed to be incorporated to allow the facility manager to efficiently complete environmental tracking tasks (e.g., predicting the spread of contaminants over time given expected precipitation in coming months). Part of this process also involved considering the application's layout of the information to ensure a highly usable workflow for the facility manager. To validate the efficiencies of our designs and underlying assumptions, we conducted a preliminary usability test early in the design process with in-house employees. The goal of this was to identify breakdowns in the current system design and workflow, prior to putting the tool in front of representative end users for functional evaluations.

Usability testing is a critical part of any design process for systems that require human interaction to perform desired tasks (e.g. creating environmental reports from compliance tracking software) and comes in many different forms depending on the type of improvements system designers are looking to accomplish. For CLEANSE, our goals in conducting usability study research were to ensure our front-end designs promote consistent and appropriate user interactions and workflows, while meeting end-user expectations for what, where, and how critical information and capabilities are provided.

The usability testing process entails studying how an end user (such as a military training facility manger) may use a type of product or service to achieve specific goals with respect to effectiveness, efficiency, and satisfaction [2]. There are several parts of user experience that may be evaluated at different phases of the design process. For our informal usability testing of the DSS design, we focused on the holistic user experience of the application. Holistic experience emphasizes on the performance and satisfaction with users' tasks and the achievement of defined tasks in specific contexts [3]. Metrics that are collected are usually qualitative and involve observing and deciphering the user's ability to complete specific tasks.

Below, we describe our method for testing the usability of CLEANSE for military training facility managers to collect user information on three key aspects of the system. The first aspect was to assess how functional CLEANSE was to outside users that were not specifically training facility managers to test how easy it was for any outside user to quickly learn the system's workflow. Second, we wished to gain perspective on the intuitiveness of CLEANSE's features and visualizations; specifically to analyze if they gave enough information for non-experts to understand the implications of the environmental effects of contaminant release. The third aspect was the ability of CLEANSE to enable facility managers to strategize and plan for the removal of released contaminants. Below, we describe our process for structuring the usability test which included creating a hypothetical use-case scenario and specific user tasks to address all of the system's components. Next, we describe the main results discovered from observing our participants' attempts in completing these tasks and provide an example of some of the initial design changes we have made based on these results. Finally, we discuss the limitations of this approach and discuss our planned future work of ensuring a highly-usable CLEANSE end product.

## II. Structuring the Usability Test

### A. *Creating the Usability Format*

To begin planning for the structure of our usability testing event, we decided to informally track a few selected metrics. These metrics included tracking the length of participants to complete certain tasks, observing areas where a user may click first when trying to complete a task during the test, and noting any workflow interruptions where the user struggles to complete tasks on the first attempt. These metrics were not quantitatively tracked but rather informally observed during the usability testing event to allow us to concentrate on understanding participants' cognitive process when interacting with CLEANSE. These metrics also assisted the design team in quickly identifying breakdowns that existed in the system.

Next, we created evaluation materials by first constructing a scenario to familiarize our participants with the purpose of CLEANSE and provide them with how a facility manager might use CLEANSE to complete a hypothetical task. The scenario was constructed based on previous knowledge elicitation (KE) sessions we held with a retired colonel of the United States Army who had experience managing training facilities. During the KE session, we asked him to describe types of environmental events where the facility manager may need to conduct analysis and planning activities. One of the more frequent events mentioned was an emergency contaminant spill by a squadron operating a tank during a training event. In this type of event, the squadron reports the spill to the short range crew manager who is onsite overseeing procedures of training exercises. The short range crew manager reports this event to the facility manager and makes sure the squadron complies with the procedure for initial removal of the spilt contaminant which is an initial topsoil dig. Even after removing the topsoil, there is leftover contaminant that remains within the environment which will eventually migrate to nearby groundwater sources. The facility manager would then be in charge of tracking the status of the remainder contaminant and scheduling a more permanent mitigation exercise for final removal. Our scenario was similar to this event where tanker fluid containing a mixture of petroleum, oils, and liquids (POLs) was released in a specified training area. The participant would take the role of the facility manager and complete a series of steps for planning future mitigation techniques for final removal of the POLs.

The series of steps we created reflected a broad array of daily tasks for facility managers, and as a result invoke all five CLEANSE components and nearly all displays of information regarding contaminant properties and mitigation techniques. This breadth enabled us to assess the effectiveness of the CLEANSE's overall workflow support. Below we provide a brief recap of the sequence of these events by explaining the intended action of the participant with regards to the CLEANSE components they were interacting with:

- *Step 1:* Identify the emergency event by naming the time, place, type of contaminant (e.g., POLs), and any additional information regarding the spilt tanker fluid.
- *Step 2:* Analyze the potential transport rate of the POLs as they approached nearby groundwater sources and also identify if there were any other contaminant types that were in danger of hitting groundwater sources.
- *Step 3:* Research additional information regarding the POL contaminant, specifically researching relevant mitigation exercise that could be used to remove not only the POLs but any additional contaminants.
- *Step 4:* Analyze any relevant mitigation exercises based on a selected amount of critical factors they may consider when selecting a certain type of mitigation. These factors included cost of the mitigation, time that the mitigation would take to be completed, and mitigation type (was it intended for emergency removal, preventative care, or routine maintenance).
- *Step 5:* Create a preliminary mitigation plan while considering scheduling constraints.

The structure of steps was compiled into a storyboard to convey the intended user interaction within each separate component view. Storyboards are primarily used for illustrating the intended user interaction of the application and

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sharing that with the end user as a means of validating the design and interaction of the application [4]. For our purpose, we created the storyboard to help us quickly and easily identify the main problem areas of CLEANSE that participants struggled with, whether it was understanding the output of information that was included in visualizations or within the workflow of the process.

To collect high-quality data on user interactions, we provided our participants with a high-fidelity version of the DSS design. There are various methods and tools that can be used for conducting a holistic usability test such as creating a low-fidelity prototype of the application being tested and instructing the user to "talk-aloud" when asked to complete a series of tasks. For many holistic usability tests, paper prototypes are created to convey the intended interface and its capabilities in a way to promote easy design changes based on feedback from the user [4]. We have taken a slightly different approach in our holistic test by importing our static designs into an interactive prototyping environment to provide participants with a heightened visibility with how the software would interact since the software was currently in the process of being developed. Combined with our "talk-aloud" method, it also allowed us to concentrate on specific breakdowns in the workflow of our planned application where participants were moving their mouse or trying to click on buttons, exploring for functionality within the software that matched their *intentions* and immediate goals. We adopted this approach, versus more traditional heuristic evaluations, due to the usability testing taking place early in the design process whereby full software functionality was lacking and our intention was focused more on understanding how individual expectations of workflow functionality mapped to envisioned system capabilities.

### *B. Usability Testing Event*

Our usability testing event consisted of 13 participants, which were all employees of Charles River Analytics Inc. These participants were mixed between summer interns and design usability experts. Participants signed a form of consent and were provided with a description of the application's purpose, brief description of the use-case scenario and task descriptions. No identifiable or demographic information was collected on any participants. For the purpose of understanding participants thought process, we instructed them to "talk aloud" about why they were trying to select certain buttons or how they were finding the information they needed to answer the questions to complete the task questions. This "talk aloud" method allowed us to record the qualitative data we needed to improve on the design and workflow of the CLEANSE application. Each usability test ran for no more than one hour and had one moderator facilitating the test and a second moderator recording notes on the participants' behaviors.

## III. Results

The results from the usability sessions afforded opportunities to identify usability gaps of both low-level design issues (e.g. confusion over color of visualizations, lack of understanding certain labels) and high-level workflow issues (e.g., confusion with how to navigate through multiple components of the application to find needed information). In general, participants understood the purpose of the application and the information that was portrayed from supporting visualizations. Below, we explain three examples of key design areas within the application's components we are working to improve in preparation for future usability tests and product development:

- The CLEANSE scheduling capability was non-intuitive and resulted in frequent errors
- User-defined note taking capability was found to lack sufficient depth and organization
- The CLEANSE workflow layout was non-intuitive for users trying to navigate through the application

### *A. Scheduling Capability*

Our original scheduling tool (Figure 1) combines scheduled training exercises with scheduled mitigation exercises and lists any spontaneous events that may have occurred (such as the tanker POL spill) in a specific training area. Results indicated that the system failed to promote effective comprehension of the information displayed in the scheduling tool with the combination of all events within the single scheduler and would find it easier to view training events and mitigation exercises as separate entities.

### *B. User-Defined Note Taking Capability*

Within the "Overview" component of CLEANSE, we have provided the user with an area that organizes annotated user notes from various team members regarding a specific training area and any environmental problems within the training area.

For the usability test, our user notes section included information regarding the progress of developing a mitigation

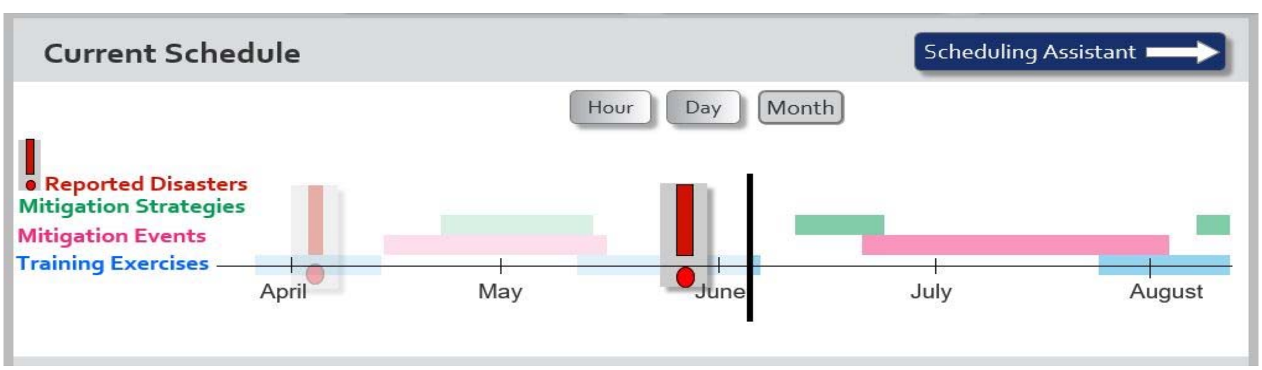


Fig. 1. The original scheduling widget showing a combination of scheduled training, mitigation, and emergency events. Participants had problems understanding the layout of the combined schedule structure.

plan for the spilt POLs. The original "Notes" section is shown in Figure 2. Participants had issues with understanding the structure of the information provided by the notes.

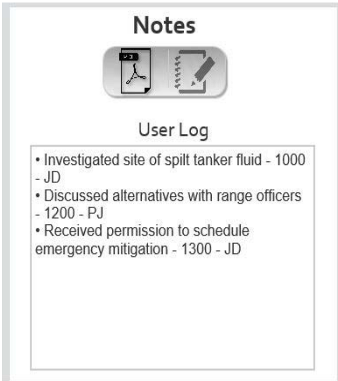


Fig. 2. The original user notes where participants had problems understanding the types of information without having an organized structure.

### C. *Workflow Layout*

The third system aspect that was observed to result in user confusion was the general layout of the application as compared to the common task workflow sequences. Our intended interaction was for the participant to first set up a search filter according to cost, time, and mitigation type. Next, we predicted the participant would select the types of contaminants they wished to mitigate. After pre-selecting these search filters, the participant could perform a mitigation factor analysis to view the feasibility of relevant mitigation. During the usability test, we observed that participants did not begin this assessment by setting the search filters but proceeded to immediately select the contaminants they wished to mitigate. We hypothesize the reason for this is the lack of alignment between the search filters and the contaminant selection panes. Another reason for this may be that the search filter is placed in a small area in comparison to the rest of the component which de-emphasizes its importance and visibility.

## IV. System Enhancements

Based on the results of the usability evaluations, the current progress towards implementing design revisions are described below. For reference, Figure 3 then provides a screen capture of the current state CLEANSE interface that has been revised based on the full set of results collected from these early usability evaluations.

### A. *Information Structure*

To address the errors encountered with the CLEANSE scheduling capability we have provided a larger scheduling tool that lists the all the mitigation exercises currently scheduled below the scheduled training exercises. The mitigation schedule is further separated into specific mitigation exercise categories: emergency, maintenance, and long-term monitoring (Figure 4).

### B. *Organization of User Notes*

The participant can interact with the new scheduling tool by selecting a training event and being alerted to which mitigation exercises are occurring in conjunction to the training events. This provides an easier way for facility managers to view any potential conflicts that may occur due to the current training and mitigation schedule. To address the feedback and confusion we observed when participants interacted with the user notes, we have added specific information fields (Figure 5): time of note, note provide an organizational layout. We have also added in the functionality for users to add new notes, edit notes, or remove notes, for additional functionality and flexibility with managing user notes.

### C. *Confusion of Navigating Workflows*

To provide a more intuitive workflow between the various components within CLEANSE, we plan to place the pre-selection factors in a left-to-right workflow rather than a top-to-bottom because it is more natural for humans to read from left-to-right. We will also change the area for each of these

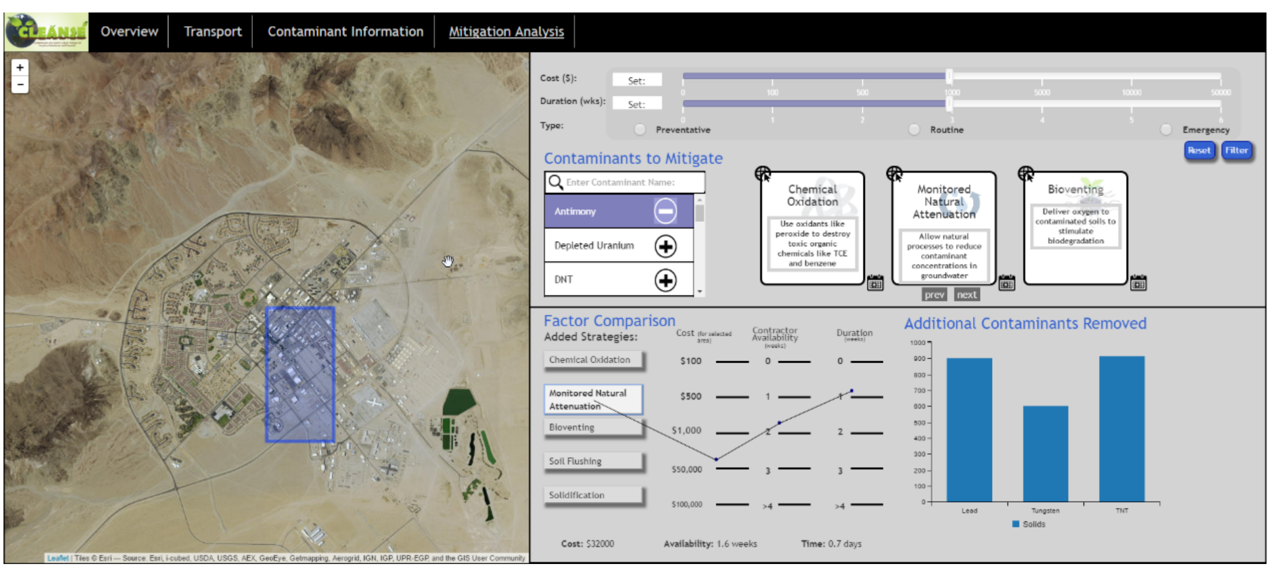


Fig. 3. The revised CLEANSE application interface showing the Mitigation Analysis view.

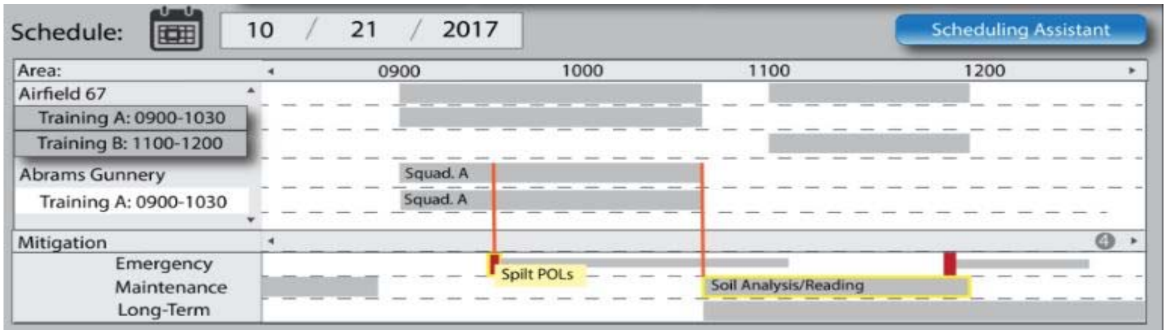

Fig. 4. The revised scheduling widget with separated training and mitigation exercises. The facility manager can select a specific training area and see which types of mitigation exercises are linked to mitigation events.

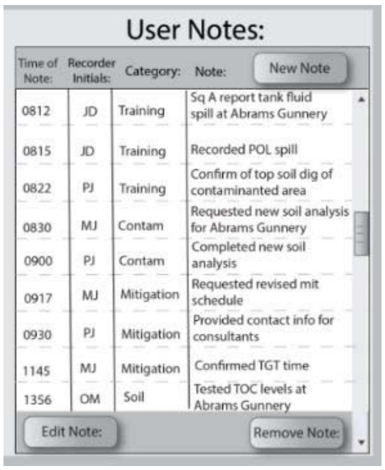

Fig. 5. The revised user notes that show information categories to allow greater organization in separate information fields.

functionalities to emphasize importance for the facility manager to pre-select critical factors before performing a mitigation factor assessment.

## V. Limitations

The usability evaluations were conducted to support the engineering design of the CLEANSE software application. As such, these evaluations were conducted with in-house employees rather than domain subject-matter experts; however, the authors felt this was acceptable for the purpose of evaluating the usability of the application as opposed to the operational / functional benefits it is intended to provide to domain expert users.

During the preparation and usability testing event, we encountered several limitations that we plan to address in the system design, which will be validated through a second round of usability tests. First, we found that while the interactive prototyping software we used was useful in showing some of the intended interactions it was very difficult to simulate the complex interactions portrayed through the customized visualizations designed to show contaminant transport behavior. In our next round of usability tests, we plan on using the actual CLEANSE software rather than the interactive mockup. Finally, the participant population we used for this round of usability tests only consisted of Charles River Analytics employees and were not representative of the user population. In our second round of testing, we will use actual range controllers, existing facility managers, and environmental scientists as our participants to further validate the usefulness and usability of the CLEANSE application.

## VI. Future Work

The remaining process for development of the CLEANSE application will include translation of the dynamic mockups to a full-feature software application. This will be accomplished by adopting the same iterative incremental design and evaluation cycle that has been presented in this paper. Moving forward, as we prototype functional capabilities that are backed by appropriate environmental science and contaminate datasources, these iterations will shift from informal usability testing to more formal usability and functional performance assessments with active DoD facilities managers and representative users from industry.

## VII. Conclusion

While our first round of usability testing identified areas of the CLEANSE software application that can be improved to facilitate better understanding and workflow execution the general consensus was that the tool did effectively enhance users' awareness of range plans, potential contamination events, available and appropriate mitigation strategies, and timeline and vendor constraints for execution of said strategies. This enhanced situational awareness will significantly improve the quality of US military facilities' environmental control and protection programs.

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