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# An Evaluation Framework for Handheld Devices within the Refinery Industry

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## Abstract

A framework is developed for evaluating the use of handheld computer devices within the refinery process industry, with a focus on the field operator. While mobile computing provides enormous opportunity, this domain has been a slow adopter of the technology. The framework combines usability components with industry best practices and aims to provide the industry with a tool that can be used as a measuring stick. More specifically, the framework uses lessons learned from industry to assemble 17 recommended practices (pre and post deployment) and 16 usability factors bound within a general system acceptability theory. Finally, the framework proposes five general management goals of implementing the technology: (a) reduce costs, (b) support processes, (c) simplify logistics, (d) improve data collection, and (e) improve safety. The framework is used to evaluate a refinery site within the U.S., by collecting data from both management and field operators. The evaluated site is an experienced user of the technology and uses current technology. However, it was found that system acceptability was hindered by 12 underdeveloped handheld-use goals, 12 poorly met system usability factors, and the absence of 7 industry best practices. The implications of this study are that, while the capabilities exist, successful implementation and use of the technology requires careful planning and evaluation.

## Keywords
Handheld Devices, Process Industry, Usability

## 1. Introduction
The purpose of this study was to investigate the use of handheld devices within the refinery industry, with a focus on end user usability for the field operator. Another common use for handheld devices is for maintenance, conducted specifically by maintenance personnel. Investigating the use of handheld devices is multifaceted in that there are multiple dimensions which could be pursued. Hence, the scope of this study was narrowed down to investigate how the technology is currently being used by field operators (within the production department) and identify areas for potential improvement. Through the development of a research evaluation framework, the study established a mechanism in which two targeted areas, usability and industry best practices, are connected to overall site management goals for handheld devices. The following sections will provide a brief overview of literature and then lead into how the mentioned framework was developed.

### 1.1 Motivation
Two key questions, which are often of interest to management within the industry, are:
1) How could handheld devices be evaluated for the field operator?
2) What are the aspects of handheld devices which could potentially be improved to provide better value?

These questions were targeted within this study for several important reasons. Handheld devices are relatively new to the industry and being able to evaluate their use and value has been difficult. Having a structured framework for evaluation could provide much needed guidance. Furthermore, it is critical that we are able to pinpoint the features and characteristics of handheld device use which either help or hinder processes. Over time the technology continues to improve, but it requires proper analysis of the current state of the technology. Improvements to handheld use could be directly related to improved achievement of primary site goals such as reduced costs, improved data collection, or improved process and equipment reliability.

### 1.2 Technology Review
Portable computer technology continues to accelerate as the consumer cell phone market pushes for faster, lighter, and more user-friendly devices. Commercial and industrial applications of this technology are therefore also

undergoing constant improvements, whether it is battery life, memory, or wireless capabilities. The devices which exist today have many capabilities which could be successfully used to improve existing industrial processes. The wireless connectivity options available today allow for device to device and device to mainframe communication. This feature can bring cost reduction within the process industry by increasing communication between systems and increasing overall efficiency. The major obstacles to wireless communication within the process industry continue to be achieving high reliability and safety within networks; and the progression of establishing international standards through ISA (International Society of Automation) and IEC (International Electrotechnical Commission) will help ease some of these concerns [1]. Some standards which are proposed for industry include systems which use a IEEE802.15.4 physical layer are: ISA 100.11a, WirelessHART, and ZigBee. Wi-Fi (2.4GHz) is a license-free alternative but issues with coexistence need to be addressed to ensure system reliability. For more about these, and additional, alternatives and recommendations for the process industry see the reviews by Hayashi and colleagues [1] and Paavola [2]. This study did not focus on wireless capabilities and therefore simply provides some background on this area.

Aside from wireless communication, there are several other key functional capabilities which should be noted. The ability to log data is one of the primary benefits of a handheld device. Data could be logged in several ways. The user could freely enter data as specific values, notes, or remarks. In addition to that, the device could automatically record data based on proximity to sensors, for example, or by geo-location. This can be achieved, for example, by the use of barcodes, Radio Frequency Identification (RFID) tags, Waypoint identification, and even GPS. This capability allows for efficient and consistent methods to collect data which could be used for trend tracking [3]. Another capability of handheld devices is being able create alerts for items which may require attention. This can be achieved through numerous methods; some include: audible alarms, flashing lights, email notification, text notification, or graphical displays. Finally, the device itself could provide the user with valuable information which could assist with decision making or provide instructions on required actions. Examples of this include documentation, checklists, guides, procedures, and trends displays. This study investigated some of the capabilities being used within the conduction of rounds by the field operator at a refinery site.

### 1.3 Handheld Devices in the Refinery Industry

The refinery industry does present additional challenges which other industries do not necessarily experience with handheld device use. The handheld device must be intrinsically safe so that it does not present a combustion hazard around flammable gases. The environments may contain a lot of noise which makes it difficult to use speech or audio for communication. Moreover, interaction with handheld devices and other objects often requires that operators use gloves which can inhibit hand dexterity. Field operators typically perform the following tasks: taking lab samples, maintenance preparations, preparing lineups, and conducting surveillance rounds [3]. This study is focused on the task of conducting surveillance rounds as this activity requires that operators input data into the handheld device, but all tasks could potentially make use of handheld devices in one form or another.

### 1.4 Field Operator Rounds

Field operators within the process industry need to conduct physical inspection of the equipment on a daily basis for the primary purpose of preventing breakdowns and alarms. While alarms may trigger corrective action on the part of the field operator, most of the times alarms occur on a predictive basis and do not require action [4]. Physical inspection of equipment requires that operators use multiple senses to judge whether anything is out of the norm. This provides the facility with information which could not be obtained inside a control room. Hajdukiewicz and Reising [3] describe a typical round as: 1) check equipment and record readings, 2) compare readings with limits, 3) if within limits, then proceed to next task, 4) if outside of limits, then conduct corrective action or the required additional steps, and 5) notify the proper personnel if any issues are observed. In addition to checking for potential points of concern, a benefit to regularly conducting rounds is that it allows the operators to map the digital representations of the process with actual machine components and maintain a better understanding of the process [4]. It is imperative that handheld devices not only assist with data collection during rounds, but also enable the operator to better perform his/her job. Hajdukiewicz and Reising [3] also suggest that “to be effective, mobile devices and applications need to integrate into the field operators’ work processes and integrate with other plant information systems, as opposed to creating ‘new work’ for the operator” (pg.1155). To this point, this study investigates the usability of handhelds at a refinery site through direct observations of rounds being conducted, interviews, text input experiments, and usability questionnaires.

## 2. Evaluation of Handheld Devices

Handheld devices, as portable computers, are vastly different than desktop computers. Even though handheld devices possess the power and capabilities of desktop computers, the method of interaction between the two is starkly different. The lack of a large screen, a full size keyboard, and a mouse are just three examples of the differences. The evaluation of handheld devices requires that usability includes factors which account for the mobile aspect of this technology. For example, a handheld device must assist users with daily tasks and not overwhelm them [5]. Other important factors which could lead to the failure of mobile systems could be related to social, legal, and economic issues [6]. Cochran and Bullemer [7] pointed out that successful implementation of new technology requires that solutions involve both sociocultural and technological aspects. They further concluded that: "the adoption of new user support technologies will require a change in the process industry's culture; need to be careful not to plan/design/buy these systems entirely with respect to current models of doing business" (pg. 5).

There have been several models suggested to evaluate mobile devices. The traditional technique often conducted with computerized systems is a heuristic evaluation [8]. However, this technique has been found to poorly identify usability problems within a more contextualized setting, such as collaborative work [9]. This is because this technique involves a heuristic inspection by an expert, who is not the end-user. It is a technique which should primarily be used in the development phases rather than post-deployment. Extensions of the traditional heuristic approach have been developed to overcome some of these contextual limitations [10]; heuristic walkthrough and contextual walkthrough are two of these. The former involves the combination of a heuristic evaluation and examples of scenarios of use, while the latter involves an actual field evaluation. This demonstrates the importance of conducting handheld device use evaluations within the proper context (i.e. within the actual environment in which they are used).

In addition to some form of heuristic evaluation, there are other techniques which have shown promising results. As suggested by Jones and Marsden [11], they include: experimental evaluations, questionnaires, interviews, direct observation, conceptual model extraction, and quick and dirty methods. They add that while experimental evaluations may provide more direct findings, they are often affected by the fact that it is difficult to manage experimental studies for mobile computing settings. In other words, by controlling for factors within an experiment, the behavior and or interaction of the user and the device is changed. This study makes use of several evaluation techniques in order to capture data from multiple perspectives; data is collected from a refinery site visit through interviews, direct observations, questionnaires, and experimental evaluations.

## 3. Evaluation Framework Development

### 3.1 Industry Management Goals of Handheld Device Use

Industry management goals were identified through a review of handheld literature [3] and Abnormal Situation Management (ASM) Consortium member reports. Many of the same goals were found within multiple sources, which validate them as actual goals which companies have attempted to achieve through the implementation of handheld devices. It should also be noted that while these are defined as management goals, many of these are also shared by the end user. From these, five general categories of goals were created: Reduce Costs, Improve Data Collection, Support Processes, Improve Safety, and Simplify Logistics. Each category goal contains sub-goals which could be prioritized specifically by individual sites. The framework therefore begins with these goals at the top of the hierarchy. The identified goal categories and sub-goals are shown in Table 1.

Table 1: Industry management goals for handheld device use

| Goal Category | Sub-goal |
|---|---|
| A. Reduce costs | (1) Reduce operational costs (maintenance/other) |
| B. Support processes | (2) Improve equipment reliability |
| | (3) Improve operational efficiency |
| | (4) Standardize processes and procedures |
| | (5) Simplify maintenance/inspection tasks |
| | (6) Provide immediate support information |
| | (7) Reduce reporting/task errors |
| | (8) Enable required environmental/compliance reporting |

| | |
|---|---|
| | (9) Provide decision support |
| C. Simplify logistics | (10) Increase management effectiveness<br>(11) Improve coordination/logistics<br>(12) Support collaboration<br>(13) Reduce paperwork |
| D. Improve data collection | (14) Simplify communications of process parameters<br>(15) Support anomaly reporting<br>(16) Enable trend and other process data analysis<br>(17) Enable multimedia data collection |
| E. Improve safety | (18) Improve safety (i.e. location tracking) |

### 3.2 System Acceptability – Usability Theory

*Usability* is a human factors term which contains multiple dimensions [8]. There are many definitions for the term but all are centered on how well the user interacts with a product. Formally, the International Organization for Standardization (ISO) 9241-11 defines usability as “the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use” [12]. This definition contains some of these dimensions of usability, which are closely related to context-of-use. At a refinery site, the users of handheld devices encompass multiple user levels. The primary users are the field operator and these individuals use the devices directly to accomplish specified tasks, such as conducting rounds. Likewise, maintenance personnel may be another group of primary users. Secondary users would be those who use the devices less frequently, such as IT personnel or others who are responsible for updating the software. Finally, tertiary users are the managers and are those who never use the device but are responsible for the management of the devices. These users would be responsible for purchasing the equipment for example. As it can be seen, each user level has different individual goals with the handheld devices, but the overall goals discussed in the previous section are the main underlying goals in which management hopes to achieve. The field operator would have lower level goals, such as being able to enter data easily and using the handheld device to assist with the general task of conducting rounds. The environment of use of the handheld devices is also different for each user. The field operator may use the handheld device in the field, while the IT professional may use it in the office. All of these factors are considered when defining the context of use for handheld devices within the refinery industry.

Nielsen [8] lays out a *System Acceptability* structure, shown in orange in Figure 1, which places *Usability* as one dimension within many. He states that in order for a system to become accepted, both *Practical* and *Social* aspects of the system must be satisfied. This study assumes that handheld devices are socially accepted within the industry, and within the larger community (i.e., the devices do not present any social issues). This assumption was largely based on the prevalence of a similar technology within the consumer market, personal smart phones. *Practical Acceptability* is the area this study investigated. More specifically, it is *Usability* within the *Usefulness* category which this study focused on. *Functionality* refers to the capabilities of the device and *Usability* relates to how those capabilities are used. The capabilities of the handheld devices on the market are assumed to meet most expectations for the refinery industry, and therefore this study is focused on how user-friendly these devices are. Other categories under *Practical Acceptability* - such as cost, compatibility, and reliability of the device – were not investigated deeply in this study. Although these are very important factors to achieving overall *System Acceptability*, they were out of the scope of this study. Moreover, as this study collected data from a refinery site which had already been using handheld devices for multiple years, these factors were assumed to have already been satisfied.

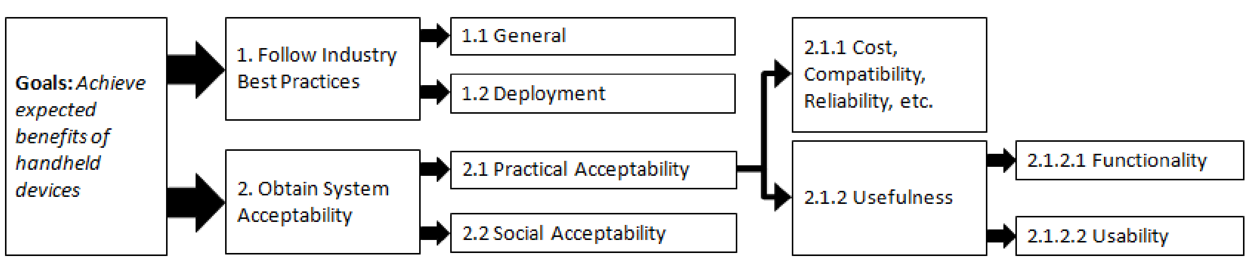


Figure 1: Framework with System Acceptability Theory

*Usability* was chosen as the primary research area because this study was focused on how field operators use handheld devices while conducting rounds. The interaction with the handheld device within the environment is an important aspect within the technology's implementation within the refinery industry. This is because the environment in which these devices are used is unique and often dangerous, compared to other industries which make use of handheld devices. Within *Usability*, there exist multiple dimensions which have an effect on how users interact with the device. Dadashi [13] conducted a thorough review of these usability dimensions and those which have the greatest relevancy to the refinery industry were chosen for this study. In addition to those, another detailed review of handheld usability by Lewis and colleagues [14] provides two other dimensions which were chosen for this study: Anthropometry and Input. Anthropometry is used to evaluate the ergonomics of the handheld device. The use of one hand or both hands is an example of this. Therefore, the size of the device, as well as the size and comfort within the hand(s), are factors which can influence overall usability. Input is focused on how information is entered into the device. Therefore, the method of input (i.e., keyboard, touchscreen, stylus), the speed of input, and the ability to avoid errors, are some additional factors which were investigated within this study. The complete list of usability factors chosen for this study, and how each relates to the overall goals, is shown in Table 2. They are ordered based on the number of goals they impact.

Table 2: Usability factors for the field operator

| Usability Factor | Explanation | Helps with goals: | | | | |
|---|---|---|---|---|---|---|
| | | A | B | C | D | E |
| 1. Portable | Size, weight, how it is carried/stored/moved | | X | X | X | X |
| 2. Error prevention | Device helps prevent errors | X | X | | X | X |
| 3. Feedback | Device provides useful feedback | | X | | X | X |
| 4. Productivity | Device helps increase productivity | X | X | | X | |
| 5. Workload | Device helps decrease workload | | X | | X | X |
| 6. Easy to use | Degree of ease to use the device | | X | | X | |
| 7. Efficient interface | Well-designed interface for use | | X | | X | |
| 8. Consistent | Functions are similar to other technology | | X | | X | |
| 9. Relevancy to task | Proper use of images and words related to task | | X | | X | |
| 10. Help | Help information is available on the device | | X | | X | |
| 11. Adaptability / Flexibility | Ability to change behavior while using the device<br>Ability to modify existing device functions | | X | | | X |
| 12. Reliable | Device is fast and dependable | | X | | X | |
| 13. Anthropometry | Size of the device, 1 or 2 hand use, glove use | | X | | X | |
| 14. Data input | Method of input, errors, speed, etc. | | X | | X | |
| 15. Durable | Device is durable | X | | | | |
| 16. Affective | How operators feel about using the device | | | | X | |

**3.3 Industry Best Practices – Lessons Learned**

In order to capture lessons learned, as best practices, the framework includes an *Industry Best Practices* component as shown in Figure 1. After a review of literature, two main categories were established for best practices: *General* and *Deployment*. *General* best practices relates to overall lessons learned with handheld devices from industry. *Deployment* best practices is more focused on lessons learned during the implementation of handheld devices in the industry. While these two categories separate individual lessons learned, the categories are strongly interconnected and thus most items identified as 'best practice' could fit into either category. Table 3 lists the practices which were identified and used within this study. These are listed based on the number of goals they impact.

Table 3: Industry best practices and how they relate to goals

| Best Practices | Helps with goals: | | | | |
|---|---|---|---|---|---|
| | A | B | C | D | E |
| *General* | | | | | |
| 1. Anomaly reporting | X | X | X | X | X |
| 2. Updated information | X | X | X | X | X |
| 3. Track Key Performance Indicators (KPI) | X | X | X | X | |
| 4. Have software support | | X | X | X | |
| 5. Have hardware support | | X | X | X | |

| | | | | |
|---|---|---|---|---|
| 6. Proper applications | X | X | X | |
| 7. Obtain/maintain strong operator buy-in | X | X | X | |
| 8. Proper IT infrastructure | X | X | | |
| 9. Feedback on data logging | X | X | | |
| 10. Keep device interface simple | X | | X | |
| *Deployment* | | | | |
| 11. Conduct proper training | X | X | | X |
| 12. Have a site champion | X | X | X | |
| 13. Use a multifunctional team | X | X | X | |
| 14. Immediate IT support available | X | X | X | |
| 15. Work process enabled by handheld device | X | | X | |
| 16. End user trust established prior to deployment | | X | X | |
| 17. Ongoing regular feedback on business benefits | | | X | |

## 4. Case Study – Evaluation of a Handheld User Site

The handheld evaluation framework, as shown in Figure 1, was tested in the field at one refinery site which has been using handheld devices for multiple years. Collecting the necessary data for establishing the current state of the refinery site among the three dimensions (Site Management Goals, Usability Factors, and Best Practices) required that multiple methods be used. The protocol for data collection consisted of both management and field operator interviews. The site visit was scheduled for a full two days. Prior to the participation of managers and field operators, an introduction into the study was communicated and a formal voluntary consent form was reviewed and signed by each participant.

### 4.1 Protocol

The data collection process followed a process which prioritized field operators. Hence, observations of field rounds were first scheduled. Two researchers filled out observation forms and time-stamped all events with synchronized wrist watches. Immediately following the observation sessions, semi-structured interviews were conducted with each field operator. After the interview session with a field operator, a text string input experiment was conducted. A data collection sheet was completed by recording the following: method of input, use of one or two hands, time (seconds) to complete each text string, and number of character errors for each text string. The operator was instructed to open an area on the handheld device in which they could enter notes and then proceeded with a practice test string. After the practice trial was successfully completed, three experimental trials followed (with three alternative text strings). Finally, the operators were then asked to complete a usability questionnaire which focused on the usability factors presented in Table 3. The questionnaire contained 42 Likert scale questions which ask the operator to rate their agreement to statements. This concluded the data collection protocol from field operators; it typically took 3-4 hours per operator.

Several supervisors/managers were also interviewed, one of which was the site reliability engineer who manages the handheld program on the site. These semi-structured interviews also had audio recordings taken with prior permission, and again, were only used for data analysis. The underlying goal for interviewing management was to collect information on: the perspective of management for using handheld devices while conducting rounds, the business objectives for using handheld devices, and the general site practices. As all interview questions were fairly open ended, other relevant information in regards to handheld use was collected and included in the analysis. Table 4 shows which methods of data collection were used to gain insight into: site goals, usability parameters, and site practices.

Table 4: Data collection methods used to complete handheld evaluation

| | Goals | Usability | Practices |
|---|---|---|---|
| Observation | X | X | X |
| Interview | X | | X |
| Text Input Experiment | | X | |
| Usability Questionnaire | | X | |

### 4.2 Participants

The general participant demographics are presented in Table 5. All participants were male. Four field operators were observed conducting rounds and conducted the text-input experiment. However, only three of those operators were interviewed and completed the usability questionnaire, as time did not allow for the fourth operator to complete the entire process. The experience level of the field operators ranged from 6 months to 10 years, and their ages ranged 26-45 years. Three managers/supervisors were also interviewed. Their experience within the industry ranged 6-10 years, and their ages ranged 36-55 years. One manager was the site reliability engineer and the other two were area supervisors (directly responsible for managing field operators in their respective areas).

Table 5: Participant demographics

| | Field Operator | Management |
|---|---|---|
| Count | 4 | 3 |
| Gender | All male | All male |
| Age Range | 26-45 | 36-55 |
| Field Experience | 0.5-10 years | -- |
| Industry Experience | 0.5-10 years | 6-10 years |

**4.3 Data Analysis and Results**

The evaluated site's management goals were analyzed primarily through the interview data of management personnel, and partially supported by observation data of the field operators. Direct observations of operator rounds produced a structured data sheet which also contained additional notes on operator behavior. The data was used to help determine the presence of site goals and site practices, along with the interview data. A goal was categorized with one of three possibilities: evidence for goal, evidence against goal, or not able to be determined. Table 6 summarizes the areas which were found to be lacking for industry management goals of handheld device use. These are potential areas for improvement which will bring additional value for using the technology.

Table 6: Results summary for lacking management goals

| Sub-goal | Findings |
|---|---|
| (1) Reduce operational costs | Existing goal, but numbers are not available to track |
| (2) Improve equipment reliability | Existing goal, but better tracking is recommended |
| (3) Improve operational efficiency | Existing goal, but multiple efficiency metrics should be tracked (equipment conditions detected / caught prior to failure or outage for: exchanger fouling, catalyst degradation, bearing temperature exceedances, etc.) |
| (5) Simplify maintenance/inspection tasks | Not a site goal, could potentially bring additional value |
| (6) Provide immediate support information | Not a site goal, could potentially bring additional value |
| (8) Enable required environmental/compliance reporting | Not a site goal, could potentially bring additional value (There is interest for this among management) |
| (9) Provide decision support | Existing goal, but operators could be provided with more information than what is currently being done |
| (11) Improve coordination/logistics | Existing goal, but regular feedback is lacking |
| (12) Support collaboration | Not a site goal, could potentially bring additional value |
| (16) Enable trend and other process data analysis | Existing goal, but limited trend analysis is being done |
| (17) Enable multimedia data collection | Not a site goal, could potentially bring additional value |
| (18) Improve safety | Not a site goal, could potentially bring additional value |

Industry practices were determined in a similar fashion to the methodology used for goals. Table 7 summarizes the industry practices which were found to be lacking in some form.

Table 7: Results summary for industry practices of concern

| Usability factor | Findings |
|---|---|
| 2. Updated information | Notes are not included in the main information system |
| 3. Track Key Performance Indicators (KPI) | Metrics related to cost, efficiency, and reliability attributed to handheld use are not readily available |
| 6. Proper applications | Many requests for additional applications (i.e., reference charts for oil, pump and turbine information) |

| | |
|---|---|
| 7. Obtain/maintain strong operator buy-in | Many operators do not use handhelds in the field |
| 9. Feedback on data logging | Operators get feedback on maintenance work orders, but not on the regular data collected from rounds |
| 15. Work process enabled by handheld device | While some operators use the handheld in the field, others wait to get back to the control room to fill in the information |
| 17. Ongoing regular feedback on business benefits | Operators do not get feedback on how the data creates any benefit |

The observation data was partially used to help determine usability with the handheld device, but more particularly in respect to the anthropometry factor. This provided data on how operators used the device physically (i.e., one hand versus two hands). Like the interview data analysis, the data provided evidence for a specific parameter, against it, or neither. The text input experiment briefly investigated the input functionality and usability of the handheld devices. There were three main categories of data which were analyzed for this text input experiment. The first category was the description of how the operator chose to input text into the device (i.e., buttons, stylus, on-screen keyboard). It was also recorded whether the operator was using gloves and the number of hands needed. The remaining categories were quantitative measures, which included the time to complete a text string (in seconds) and the number of character errors made within a text string (including blank spaces). Averages between the four field operator participants were calculated for each text string (as each contained a different number of characters). In addition, the speed of typing text in wpm (words per minute) was calculated by averaging the time it took the operators to type the number of words they actually completed. Similarly, errors-per-minute was calculated, making use of the speed calculated previously to obtain a rate. Only these last two metrics are reported here.

The field operator usability questionnaire was primarily used to investigate the usability aspect of the handheld device. The questions were typed statements in which operators were asked to rate their agreement to each statement on a 7-point Likert scale (Strongly Disagree, Disagree, Slightly Disagree, Neutral, Slightly Agree, Agree, Strongly Agree, or Not Applicable). With only being able to obtain this type of data from three out of the four operators which were observed and interviewed, we simply provide the individual usability scores. Scores from this questionnaire were created by grouping like-items into the usability factor categories, assuming equal weight for each question asked. Acceptability ratings were then assigned to these grouped scores (1.0-2.0 unacceptable, 2.0-3.0 very poor, 3.0-3.5 poor, 3.5-4.5 fair, 4.5-5.0 good, 5.0-6.0 very good, and 6.0-7.0 excellent). Finally, individual verbal responses from both operator interviews and operator observation were also used to identify common themes within all of the data collected. Table 8 summarizes the findings for the usability factors and includes notes for the ones which may have room for improvement.

Table 8: Results summary for usability factors (using field operator data only)

| Usability factor | Notes (Interview/Observation data) | Usability Scores |
|---|---|---|
| 1. Portable | Some concern with not able to use device everywhere, device size concern, limited freedom of movement | 3.3 3.5 6.3 |
| 2. Error prevention | Some concern with the ease of being able to correct mistakes and presence of appropriate error messages | 3.3 4.0 5.3 |
| 3. Feedback | | 4.5 5.0 5.5 |
| 4. Productivity | Some concern with accuracy of default values | 3.7 5.3 6.3 |
| 5. Workload | Some concern with feeling overwhelmed | 3.5 4.0 4.0 |
| 6. Easy to use | | 5.2 6.2 6.2 |
| 7. Efficient interface | Some concern with ease of inputting text | 3.8 5.3 6.0 |
| 8. Consistent | | 4.5 6.0 7.0 |
| 9. Relevancy to task | | 4.5 6.0 7.0 |
| 10. Help | Some concerns with availability of help and training | 4.0 4.7 4.7 |
| 11. Adaptability/Flexibility | Some concern with being able to conduct tasks flexibly and with being able to customize the interface | 3.5 5.0 5.0 |
| 12. Reliable | Some concern with reliability and speed of uploads | 4.0 6.0 6.0 |
| 13. Anthropometry (Ergonomics) | Poor for one hand use, good for two hand use<br>Some buttons too small (decimal, arrows) | n/a |
| 14. Data input (Interaction) | Stylus is good for input, poor for speed<br>All operators prefer using stylus<br>Experiment: avg. 13 wpm, with avg. 2 character errors | n/a |

| | | | | |
|---|---|---|---|---|
| 15. Durable | Some concern with durability | 4.0 | 5.0 | 7.0 |
| 16. Affective | Some concern with liking to use the device | 4.0 | 6.0 | 7.0 |

## 5. Discussion

The findings indicate that there are some management goals (see Table 6) with handheld devices which are not currently present, but could bring additional benefits to the site if they were implemented. In addition, several goals were present but it was unclear if these were being achieved. This was because either the metrics were not available to be shared or they were not being tracked. Overall, there is room for potential improvement in all five categories of management goals: Reduce Costs, Support Processes, Simplify Logistics, Improve Data Collection, and Improve Safety. The following paragraphs provide specific areas which could be addressed within site practices and device usability, which could assist in achieving these goals.

Table 7 indicates that there are multiple handheld practices, which were identified as successful practices within the industry, to be lacking at the evaluated site. Obtaining operator buy-in seems to be lacking at the site as many operators choose to not use the handheld device in the field. While this may be a goal onto itself, it is a critical step which must be reached in order to achieve the business goals of using handheld devices. The other practices in need of improvement include: tracking key performance indicators, using the proper applications, enabling work processes, and providing feedback to operators on both their regular data input and the business benefits being realized by using the devices. All of these practices are closely tied together; success in one can lead to success in the other

Table 8 indicates that the handheld devices' perceived usability, per the field operators surveyed, could be improved in multiple dimensions. It is recommended that each usability factor is further investigated by the site to determine what improvements can be made. While some of these factors are out of direct control of the site, such as device portability, others are things which could potentially be immediately addressed. For example, factor 11, Adaptability/Flexibility, could be improved by allowing operators better flexibility on how they are instructed to do their round routes. This could then lead to better achievement of goals within Support Processes and Improve Safety. Factor 13 (Anthropometry - Ergonomics), indicates that the handheld device is designed for use with two hands. Furthermore, some of the buttons which are most frequently used (such as the decimal point button) are too small to be pushed for some operators who are wearing gloves, and even without gloves. There may be a need for a potential design change of the handheld device or of the gloves to allow for better hand-to-device fit. Factor 14 (Data Input - Interaction), indicates that the preferred method of input was using the stylus to push both the physical buttons and the on-screen buttons. Furthermore, the experimental results of stylus text input shows that it takes a significant amount of time for operators to type a message (much longer than the average seen on other portable devices, such as smart-phones). The data also shows that there could be errors in the typed message, which is undesirable considering that the message may contain critical process or equipment information. There is a need to either avoid the need for this type of interaction or provide alternative interaction options for improved input speed. Overall, the observation of rounds showed that most operators never need to input a text string and instead primarily used drop-down menu selections or the numbered buttons to input data. However, if there are instances which require text input – it should be kept to a minimum.

## 6. Conclusions

The evaluation framework, as developed here, has been partially validated within this study. The review of management goals indicated that the evaluated site could potentially improve within all five general categories (Reduce Costs, Support Processes, Simplify Logistics, Improve Data Collection, and Improve Safety). The analysis of the handheld device usability factors indicated that multiple factors may potentially have room for improvement, with these factors having an impact in the achievement of goals within each of the five goal categories. Likewise, the analysis of evaluated site's handheld practices indicated that there is room for potential improvement which would also impact goals in all five goal categories. While these findings correspond to the general framework, it is by no means conclusive. Evaluation of additional sites, especially those which better meet the targets within the framework, could result into additional insight in regards to validation of the proposed framework. Finally, directly linking quantitative information (i.e., costs) to practices, usability factors, and goals could become necessary.

While this study focused on the field operator, this framework could also be adopted to other refinery operations, such as maintenance or engineering tasks. Some refinery sites may find that this technology has been better adopted within maintenance operations. This could come about due to the differences between the tasks of conducting rounds versus routine maintenance. One such difference, which seems to play a critical role, is the temporal aspect of each task. Oftentimes, a field operator must complete his/her round in a limited amount of time, particularly on Day Shifts where other tasks also require their time, and carrying an additional device for the round could be perceived as burdensome. Conversely, a person conducting routine maintenance may have more time to complete their task, and often need to carry around more items (e.g., tools, parts, PPE). Carrying around an additional item, therefore, may not be perceived the same way. Additionally, the purpose of a handheld device may also be starkly different. A field operator may use the device to record information; whereas, a maintenance person may use the device to drive their activity (like following instructions to replace a pump). These differences have, without a doubt, significant implications on how workers experience a handheld device. Future research should also investigate handheld use within these other refinery operational contexts.

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