



SMARTPHONE-BASED INFRASTRUCTURE WORK ORDER SUBMISSION

THESIS

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AFIT-ENY-MS-15-M-000

**DEPARTMENT OF THE AIR FORCE
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THESIS

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Abstract

Air Force Civil Engineers (CE) require a constant stream of current information about facility problems to diagnose, prioritize, repair and maintain the large infrastructure inventory needed for day to day operations. Controllers currently rely on information collected via verbal submissions from facility owners, from which they create text-based work orders to repair infrastructure issues. Verbal submission has been the standard for 20+ years and is limited in its ability to diagnose the growing and increasingly complex facility infrastructure systems. Newly developed smartphone-based work order submission may hold the key to this problem.

To determine, if smartphone-based submission systems generated better submissions than traditional verbal submission systems, an experiment was designed to test the submission systems using simulations of real-world maintenance scenarios. Testing was based on the theory of media richness coupled with CE craftsmen expertise to determine key pieces of information required to repair a failing facility system. A course of broken infrastructure was laid out, and test subjects were asked to submit work orders utilizing either the traditional verbal or smartphone-based submission systems. Results based on these scenarios were then used to calculate useful information ratios which measure the effectiveness of uncertainty reduction for a work order.

Analysis revealed smartphone system had the highest useful information ratio, mitigated the communication gap between other groups and CE, and allowed any individual regardless of facility diagnostic experience to submit a work order at the level of an expert. These results show that smartphone technology is capable of not only being quickly able to relay more pertinent information to a CE craftsman, but in the hands of any Airmen, the system allows them to freely communicate with CE craftsmen as if they were facility diagnostic experts themselves. With the explosion of smartphone technology to the general public, distributing this application to base personnel turns every Airmen into a sensor. Enabling rapid and accurate response from CE repair teams limiting damage to critical systems, gaining a clear site picture after disaster, addressing reduction in cost to the most expensive part of a facilities lifecycle, and ultimately increasing the ability for the Air Force to complete its mission.

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Victor L. Guinn

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SMARTPHONE-BASED INFRASTRUCTURE WORK ORDER SUBMISSION

I. Introduction

General Issue

United States Air Force Civil Engineers maintains 33 thousand buildings covering 458 million square feet and 8 million acres of land on a daily basis. Of the 33 thousand buildings, 32.6 thousand are listed as needing repairs totaling an estimated \$17.6 billion (General Services Administration, 2015). Given limited budgets, it falls to Air Force Civil Engineers to creatively maintain this aging infrastructure in order to ensure mission continuation. Maintenance of aging infrastructure is a continuous process, and no matter the creativity of Civil Engineering, maintenance still comprises the most expensive portion of a facilities 30-year life cycle, costing up to 3 times the original construction cost (Whole Building Design Guide, 2016). This massive amount of maintenance taxes the ability and resources of individual installations, which in FY 2015 spent \$3.02 per square foot to maintain their facilities for a total of \$1.4 billion expended across the Air Force (General Services Administration, 2015). While \$1.4 billion is a large maintenance budget, it represents a 14% decrease in Civil Engineer funding in addition to workforce cuts of 1,900 personnel from 2010-2013 alone (Reynolds, 2013). Additionally, the Air Force as a whole has seen a workforce decrease of 38% since 1991, to 311,000 troops in 2017 thus reducing the availability of multiple Airmen being able to report an infrastructure emergency or potential failure.(Goldfein, 2017) During these fiscally constrained and limited workforce times, resource optimization is critical to remain agile. Civil engineers optimize resources by heavily relying on work order information management to ensure systems critical to mission success are diagnosed and maintained first. Infrastructure systems not deemed critical are documented to be in need of repair, and when funds are available, they can be brought back to full capability.

Currently, the only way to document broken infrastructure is through an antiquated system of submitting work orders through a facility manager (Davis, 2013). Facility managers attend a short training program to help them understand how to report problems, what constitutes an emergency, and a general overview of Civil Engineering. Once trained, these individuals are often assigned facility manager as an additional duty and not as a full-time position. Since the training program is short and many facility managers do not have the organic background of infrastructure maintenance new facility managers may not have the in-depth understanding of what broken infrastructure looks like or how to do the most basic facility diagnostics (Davis, 2013). Ultimately, this lack of knowledge and experience results in critical infrastructure that is in need of repair being improperly reported to Civil Engineering. Incorrect reporting of critical infrastructure is highlighted by several failures experienced by the Air Force. One such incident involved the collapse of a floor at Malmstrom Air Force Base (AFB) Montana. As a result of the floor failure, training was suspended for six months. Another failure involved the accidental discharge of a fire suppression system at Eglin AFB. The discharge damaged five aircraft, buried the facility in 17 feet of foam, and closed the facility for three months. Finally, at Tinker AFB the electrical substation failed catastrophically. Cutting power to depot maintenance facilities, and costing \$7 million dollars to repair. All of the listed failures were examples of critical infrastructure not being properly reported, and categorized. As of January 2016, there is a \$22.6 billion backlog of reported facility maintenance (Cohen, 2016). In a fiscally constrained environment being able to identify, and categorize critical infrastructure repairs becomes a necessity. This ability to categorize facility repairs and reduce the likelihood of catastrophic failure can only be accomplished through extensive data analysis and data collection.

Data collection for facility repairs in the Air Force in most locations is an additional duty. In some cases, a full-time position exists for data collection. In the Air Force, these individuals

are referred to as facility managers. Facility managers are trained by Civil Engineering to accomplish the collection of data in the form of work orders. Training also includes instruction of how to perform minor maintenance tasks on their assigned facilities. Additionally, facility managers act as the Civil Engineering liaison for their particular unit and are the only individuals permitted to submit non-emergency work orders. Simple in concept, what adds complication to the system is facility managers go through turnover on a relatively frequent basis. Inadequate transition time and poorly kept records frequently result in the same work order getting resubmitted to Civil Engineering. Resubmission causes duplication issues, and potentially false data generation, which results in poor data analysis hindering Civil Engineering from spending money on the right infrastructure at the right time. Utilizing money to repair less critical infrastructure puts critical infrastructure at risk for complete failure. Even if the system otherwise works perfectly, there typically is only one facility manager per unit, and accessibility to that individual can pose a problem. A facility manager may have gone home for the day, or the individual discovering an infrastructure problem may not even be aware of who the facility manager is. Additionally, in cases where emergency situations are in progress, individuals witnessing the infrastructure emergency may not know the Civil Engineering emergency hotline for their current location. Problems for the current work order submission system are extensive and center on the following: inability to exchange information quickly, single points of failure (personnel), lack of organizational standardization, time of the day, and dwindling Civil Engineer trained experts able to initially diagnose and respond appropriately to the infrastructure problem (Davis, 2013).

Problem Statement

Air Force infrastructure is failing on a daily basis; now more than ever it is essential to ensure the immediate diagnosis of critical infrastructure prior to complete failure. Rapid response is fundamental in guaranteeing sound infrastructure supporting weapons systems operational status (Goldfein, 2017). To support this a more efficient method to quickly submit, diagnose, and respond to problems needs to be investigated (American Society of Civil Engineers, 2013). With the advent of smartphone technology availability to a majority of the population, cities in partnership with private companies are developing community request management applications (Rittatore, 2015). Many of these applications are tailored for use as infrastructure work order submission applications. With little relevant research directly related to the effectiveness of these applications, the following study answers two crucial questions about the technology:

- 1) Does a non-CE oriented individual with minimal training, equipped with only a smartphone-based mobile work order submission application, transmit more useful information to craftsmen in the categories of geolocation and object description?
- 2) Will an increase in useful information enhance work-order duplication detection when compared to the use of the traditional verbal phone-based work order submission system?

Research Objectives

Determining if smartphone-based mobile work order applications are more effective than traditional call-in systems requires comparing three main system objectives: geolocation of the problem, description of the problem, and point of contact (Davis, 2013; Hasberry, 1991). Point-of-contact will not be addressed within the design of the study as all known systems automatically collect this information, even the traditional voice/text system. Therefore, the objectives of this study focus on the two remaining areas; geolocation accuracy and description.

Evaluation of these two areas starts with customer submission and ends with a craftsmen interpretation of the information's usefulness when diagnosing the type and extent of the repair.

Geolocation of a problem is determining where the problem is located in the physical world. One of the main challenges for geolocation is how reporting individuals relay their geolocation back to Civil Engineering controllers. An objective of this research is to measure the geolocation accuracy of the submission system based on measuring the actual geographic location when compared to the description (Maguire, Woollett, & Spiers, 2006). Accuracy will be a binary yes/no value dependent on craftsmen recommendation for proximity required to find the object. After geolocating the object, accurate description of the object is the next important objective.

Determining problem description will focus on comparing submitted work orders from the two systems against what craftsmen consider to be key data. Ideally, craftsmen need to be able to perform service on an infrastructure problem in one trip without having to perform a diagnostic run before the repair trip. Quantifying description accuracy can be accomplished by utilizing the information usefulness measurement metric, from which a correlation is made regarding the amount of uncertainty reduction for a given receiver (Daft & Griffin, 1983; Holland, Stead, & Leibrock, 1976). In this case, the receiver is a CE craftsman who also determines what constitutes useful information. As long as they receive the information they consider to be key data, it will reduce uncertainty in their understanding of the work order. Having used the metric of information usefulness to measure an object description through uncertainty reduction, and information usefulness ratio can be used to compare all descriptions from each submission method.

Finally, in addition to geolocation and description, the resistance of each submission method to accidental work order duplication will be examined. Duplication is the potential for an

individual to misinterpret the description or geolocation of an existing work order resulting in the generation of a duplicate work order. Evaluating geolocation, description, and duplication will be critical in determining which system is more effective.

Hypotheses

With the creation of Smartphone-based mobile work order submission applications, a new opportunity exists within the Civil Engineering community to harness a new communication medium. Capabilities from these types of systems outstrip the abilities of current verbal to text submission methods. These capabilities are largely an effect of expanded communication channels that smartphones afford. In the hands of customers, this expanded communication ability may be able to bridge the communication gap caused by organizational language barriers and limited facility diagnostic experience. Bridging this gap is accomplished by the sheer volume of information that smartphones collect. Quality, however, cannot be directly tied to quantity, and having a large amount of information does not mean that it has any usefulness. Current methods to test submission systems regarding delivering useful information that's actionable to CE craftsmen are lacking. Smartphone submission systems promise to allow any individual regardless of organization background, or facility experience to bridge barriers, and produce quality information. However, with insufficient studies to validate the claim, it remains only a promise.

This study is designed to explore these key areas and will do this by conducting a real-world test to validate three hypotheses. First: Smartphone-based mobile work order submission applications when utilized by any individual, will submit information at a significantly greater usefulness than when using the traditional verbal based submission system. Second: When using the smartphone-based mobile work order submission system, any individual regardless of background will submit useful information at an equal or greater level than individuals within the

CE organization. Third: Regardless of being a self-perceived facility expert, or novice, smartphone-based work order submission will enable all individuals to submit information at the level of an expert utilizing the same system. This increase in the usefulness of information transmitted to craftsmen would have the immediate result of reducing communication errors, identifying failing infrastructure prior to catastrophic failure, improving the site picture, and reducing travel, which would directly translate to the Air Force saving time and money.

Methodology

To evaluate the effectiveness of smartphone-based work order submission system compared to the traditional work order submission process, an experiment was developed. Experiment methodology was broken into four parts; scenario selection, testing, subject matter expert data coding, and effectiveness analysis.

Initial setup of the experiment consisted of simulating maintenance scenarios commonly found on an Air Force bases within the United States (US). Real world maintenance requirements were utilized as the basis for developing simulated maintenance scenarios. After determining scenarios to be accomplished by each test subject, a course was then set up through the AFIT facility.

Testing was completed in two stages, preliminary course testing and standard testing. Completion of preliminary testing included the researchers and CE Airmen experienced with facility systems. Preliminary tests smoothed out any irregularities, ensuring that the course and submission methods were sound. During testing, subjects were chosen from the AFIT student body and were randomly assigned to use either the smartphone-based work order submission application, or traditional verbal work order submission system. Subjects were then asked to complete a post-course questionnaire to answer demographic questions for future analysis.

CE craftsmen were the SME coders for the experiment. Since all data collected mimicked real world work order facility maintenance information, it was important frequent users were the ones to analyze and determine what information was important and what was not. CE SME's filled out a worksheet for each of the scenarios, listing important key data that they would need to diagnose and repair the item. Finally, statistical analysis of the experiment data was accomplished to determine relative system effectiveness.

The proposed research experiment compared smartphone-based work order submission system with a traditional verbal to text work order submission system. Testing feasibility, the methodology was broken into four parts; scenario selection, testing, subject matter expert data coding, and effectiveness analysis. An in-depth review of the methodology for this study is contained in chapter three the methodology section.

Assumptions/Limitations

As with most studies, assumptions were made in order to narrow the scope of the research, resulting in limitations to the overall study. An initial limitation to this study is the lack of a user-acceptance investigation for such mobile smartphone-based applications.

User acceptance of a smartphone application is incredibly important to ensure when the application is launched users utilize it. In the case of a work order submission system, user acceptance is critical for system effectiveness. Without a study to confirm how to gain user acceptance, the system may prove useless if individuals do not trust the system to assist them with their infrastructure problems (Lenhart, Purcell, Smith, & Zickuhr, 2010; Lepri, Antonelli, Pianesi, & Pentland, 2015). This study assumed users would accept the smartphone system, but future studies to examine the validity of this assumption would be required. Another concern, especially for the Air Force, is security and how the application could potentially pinpoint infrastructure vulnerabilities.

Application security will ultimately be one of the main deciding factors if the application may be used by a base's general population. A risk-assessment study of how the application could potentially cause a security breach will need to be completed to determine if the application is secure enough to be utilized; this security assessment would need to be focused on the entirety of the application (Sweatt, Paradesi, Liccardi, Kagal, & Pentlandz, 2014). When examining the data produced, the front end of the application if heavily utilized by a base populous would generate a tremendous volume of data. Without a backend to decipher the data, it would be nothing but pictures, coordinates, and text messages by potentially hundreds of thousands of people. Evaluation of what an adversary could gain from this data would be necessary to analyze whether or not the application could be used on an installation without unnecessary risk. This study did not address security issues to limit scope and assumed base personnel would be authorized to use the smartphone application.

Finally, instead of an actual commercial smartphone application or a fully manned call-in center, a working smartphone application, and automated voice answering system were created for the study. Production of a working smartphone application was necessary to provide realistic testing of current technology but resulted in a limitation of this research as it was not the actual commercial application. Features like the messaging assistance from a customer service unit, video, and audio submission were not available to the test subjects. Research will need to be done to determine, that even though the application used in this test mimics the real application, testing to quantify that individuals interact with both applications, in the same way, would need to be accomplished. Likewise, an automated voice answering system was necessary for this experiment to standardize the traditional call-in submission method. As a result, a Customer Service Unit (CSU) was not available to verbally guide the customer over the phone with the initial facility system diagnosis or problem description.

Implications

Utilizing this type of technology has the potential to assist Air Force Civil Engineers in making sound engineering decisions. These decisions could be based on rapid assessment and classification of infrastructure problems identified by any airmen in the field, regardless of CE experience. Smartphone work order submission technology may save both time and money by reducing travel required for diagnostics, and organizational language barriers. Additionally, the ability for nearly instant diagnostics coupled with a rapid, accurate response will ensure that aging mission-critical infrastructure remains fully operational to support a spectrum of growing worldwide missions. Smartphone-based systems provide this advantage by delivering a clearer site picture to Civil Engineering shops, and a direct line of communication with the original reporter. All these advantages help eliminate information misinterpretation, as well as quicker identification of critical infrastructure problems, giving smartphones the edge in the fight against failing infrastructure (American Society of Civil Engineers, 2013; Evered, 1980; Goldfein, 2017; IBM Corporation Software Group, 2012; Rittatore, 2015).

Conclusion

At the conclusion of the research, it will be determined if the use of smartphone-based mobile work order submission technology does, in fact, enable customers to accomplish what traditional submission systems are not currently capable of, especially in the hands of average customers. Through testing and analysis, this study will determine if smartphones deliver; a higher overall information usefulness ratio, mitigate the CE organizational language barrier, enable all individuals regardless of facility diagnostic experience to submit work orders at the same level of an expert utilizing the same method, and if geolocation and duplication detection demonstrated improvement over traditional submission methods.

II. Literature Review

Chapter Overview

This chapter first addresses two of the three main requirements for a successful work order submission: geolocation of the problem and description of the problem. Point-of-contact will not be studied as being able to capture the necessary information required to contact the original requestor is an easy task that both verbal, and mobile systems do extremely well (Davis, 2013; Hasberry, 1991).

First, the problem of geolocation will be investigated. Secondly, description of the problem will be broken into two areas. One is how individuals recognize objects, and how this relates to experience. Additionally, the differences of information transmission ability through media richness between verbal, and information-rich electronic media will be examined. Media richness will be explored to support the use of mobile applications to make up for an individual's lack of experience, though the use of pictures. The focus of this review will be on developing successful metrics regarding how to measure the efficiencies between traditional and smartphone-based work order submission systems. Initiating this review is first being able to determine the geolocation of the potential repair.

Geolocation

With base infrastructure issues, one of the first important factors required to analyze and repair a facility problem is the ability to locate the problem to repair it. Geolocation is important for the initial report of the problem, documenting the problem, and the relocation of the problem by Civil Engineer (CE) personnel to make repairs or conduct a more in depth site survey. Currently, geolocation of base infrastructure problems is tracked by facility number and base. Recording this information is accomplished with a customer service unit (CSU) interfacing with a customer and recording the data gleaned from the report into the CE Work Management System

(WMS) (Schneider, 2015). The current WMS used by Civil Engineers is known by its acronym, IWIMS, or the Interim Work Information Management System and is projected to be replaced by the TRIRIGA WMS by July 2017 (Schneider, 2015). Currently geolocation description stored by the IWIMS system is automatically installation specific with a four-letter descriptive string indicating base location. For instance, Dyess Air Force Base has the string “FNWZ,” and is only capable of storing a facility number and a brief description of the problem location; more extensive problem location descriptors must be put into a later customer description input field. With such a limited ability to record the geolocation of a repair, problems arise when the repair has unique properties that cannot be described by a facility number, a short string such as a room number, or a real property-unique identifier. The inability of IWIMS to provide accurate geolocation has resulted in duplicate work orders and wrong locations. The following are theoretical examples rooted in call center experience.

First of these scenarios is where there may be many similar object(s) in a linear/grid pattern in an area with no obvious indicators of how to describe the location of the individual object(s). Exterior examples of this would be an identical string of streetlights, airfield lights, and linear items such as fences, or pavements like roads. Interior examples of these patterns are flooring, lights, ceilings, and plumbing. Whether interior or exterior, description of the location is a two-part problem that is influenced heavily by an individual’s experience, and whether the landmarks or spatial references next to the object can be found again, or themselves are unique. Issues arise when individuals reporting the items report a general geospatial location but lack the geometric descriptive detail required to find the individual item in the pattern, resulting in wrong locations and duplications. Ability to geospatially pinpoint an item in a pattern, and ensure that none of the other items may be mistaken, is related to a human’s process of remembering landmarks, orientation, and geometric relations (Golledge, Jacobson, Kitchin, & Blades, 2000).

Second is the ability to describe a geographically hard-to-describe location, where the item exists in an area that cannot be easily described by nearby landmarks. Interior examples are areas without placards, rooms so large that numbers cannot adequately describe the location, or areas that are known by several common names. Exterior examples of this type of problem may include a hole, infrastructure leak in the middle of an open field, or a parking lot where there are no close landmarks that can easily be referenced. Not being able to describe one's location is commonly referred to as "getting lost." "Lost" is a condition in which a person loses, or never had a spatial knowledge of the area that they are trying to navigate and cannot return to their starting location or proceed to their destination. In the repair problem, the condition of "lost" is the lack of spatial knowledge required to thoroughly describe the location of the problem (Thorndyke & Hayes-Roth, 1980). These problems of a human describing their location may result from many factors including gender, education, and even cultural differences (Chang & Antes, 1987). Fortunately, this geospatial descriptive hurdle can be easily overcome with 2017 smartphone technology.

Humans' navigational abilities are subject to many limiting factors including, but not limited to spatial knowledge or limited wayfinding ability. One solution to these problems is to partially remove these limiting factors with the use of a system known as the Global Positioning System (GPS). Given 80% of smartphones are GPS capable as of the close of 2011, this technology has been widely adopted by millions of people which reduces, or completely eliminates, the humans' navigational limiting factors (Rebello, 2011). One of the primary advantages of using GPS technology is that it takes less effort to navigate or find your position accurately as compared to observing your surroundings to gain spatial awareness or trying to read a physical map to determine your location. Confirmation of this ease of navigation has been researched, and results indicate that individuals who navigate, based on their memory and

physical maps, have a larger, more developed hippocampus, which is responsible for spatial navigation and mental mapping. Individuals who do not navigate frequently, or utilize GPS navigation frequently, have been shown to have a smaller hippocampus (Maguire et al., 2006; Neyfakh, 2013). Not only is this a strong indicator that GPS does lend itself as a much easier to use technology; GPS often provides better than one-meter accuracy and can be obtained almost instantly (William J. Hughes Technical Center, 2016). For nearly all exterior CE work orders, if the geolocation problem can be narrowed down to a two-meter diameter circle, the problem will most likely be able to be located for repair. Although incredibly useful, GPS does not work well in all conditions, most notably while in buildings. Combating this loss of assistance from GPS, individuals must rely on traditional observation, wayfinding, and spatial knowledge to determine their location. Smartphones have a special capability that although not an exact way to find a geospatial position, it can be used in conjunction with little extra knowledge to determine an exact geospatial location, interior, or exterior.

Currently, the method to submit work order requires an individual to report their geospatial location by determining their location through a combination of spatial knowledge, and wayfinding. After determining their location, they submit their location verbally to the CE CSU typically via voice conversation. Smartphones have the advantage of being able to submit higher levels of information; this submission of higher level information is commonly called media richness and will be discussed later in the chapter. Even if a smartphone's ability to relay its location using GPS is hindered, its ability to take pictures makes up for the lack of not only object descriptors, but location descriptors as well. Individuals lacking in wayfinding ability, or spatial knowledge only have to know enough to describe their general location. A picture taken of the item with the smartphone by the individual can then describe the rest of space, in enough detail that a geospatial location can be determined. Harnessing the ability to use photos as part of the

geospatial description enables individuals with little knowledge, or experience describing their location, to accurately submit location information.

Integration of GPS descriptors, along with information rich pictures accompanying the customer work order submission would greatly assist with the location and repair of base infrastructure problems, especially in cases where a description of facility number and room number is inadequate to describe the problem. The ability to determine geolocation of a potential repair is critical when measuring the effectiveness of traditional work order reporting versus an alternative submission process such as smartphone-based mobile reporting. The reasoning is simple. If CE crews cannot find the location, they cannot repair the broken infrastructure. In addition to the geolocation reporting effectiveness, another area of analysis, and the next step in the process is the ability for customers to relay a description of the problem. Problem description can be broken into two parts; how the object is viewed and recognized and how the information is transmitted. How an individual “sees” the problem is the first step in this problem description.

Visual Research

Visual object recognition in relation to Civil Engineering (CE) WMS is of the utmost importance to operational engineers, determines how individuals perceive and describe objects and the environment. Being able to describe objects through an audio or written communication medium is becoming an increasingly difficult task, as infrastructure systems are becoming highly complex. As a result, this situation is creating errors in the WMS due to miscommunication. To counter this problem, CE is researching how to better submit infrastructure problems through the use of smartphones that can take pictures. Determining the effectiveness of these systems becomes difficult to measure and becomes increasingly subjective as trying to objectively measure what a human see's, and understands is a highly complex question. What is recognition?

In short, when does your brain makes the connection that what you are seeing matches the mental representation of the object and results in a meaningful definition that you can communicate?

To answer these questions. First, how objects are stored in memory as mental representations and the associated views will be examined. Second, how object representations are classified will be studied. Third, review of what a specificity level of an object is, and how it relates to experience. Finally, how processing the image takes place to recall the object representation will be investigated.

Object Representation/View Transformation

The first factor of human visual recognition is the nature of the stored representation; this is the ability for an observer to look at an object from many different views and match what they see to a stored representation. Once the match is made, the information regarding the object may be utilized. Driving theories for object representation is the view invariant and view dependent theory (Tarr & Vuong, 2002). The multiple-view theory is a combination of view invariant and dependent theory (Bar, 2003).

Viewpoint invariant theory is the classic theory of how humans recall object representations from memory. The basis of this theory is that humans store objects as a memory of a structured organization of three-dimensional components and is sometimes referred to as Recognition By Components (RBC). These three-dimensional components are referenced as geons and are comprised of approximately 36 simple geometric shapes that humans can readily perceive and understand for instance cones, blocks, and spheres (Biederman, 1987). What is unique about RBC is that no matter the change in viewpoint of the object, its relative features remain the same even though its appearance may change (Tarr & Vuong, 2002). In this way, a human can easily match the arrangement of the geons with the representation of the object stored in memory, as long as the image remains rigid (Biederman, 1987).

Viewpoint Dependent Theory is focused on object recognition based on the assumption that a person stores multiple views of an object throughout many different viewing conditions such as differing illumination, and viewpoint. Individuals recognize the entire object and the context that it is in rather than in parts; their recognition performance may be hindered by the viewing conditions around the object when the object was originally learned (Tarr & Vuong, 2002).

Multiple views theory is the assumption that object recognition occurs both invariantly and dependently. With multiple views theory, invariant views control the image specificity, and dependent views control the category. This theory in some references is related to top-down processing (Bar, 2003). When reviewing the definition presented the referenced processing is actually parallel processing (Berg & May, 1997). This powerful theory explains a human's ability to react when only partially available visual information is available. Ability to react under this theory can occur by being able to have an initial dependent view of an object, where only the edges may be perceived; this initial view starts to activate the classification areas of the brain for objects with those types of edges starting an initial guessing process. If the object's representation can be directly recalled with the current dependent view, the process stops, and the object is known. If the object cannot be readily understood, the process starts to integrate with bottom-up viewpoint invariant processes that start to break down to create a new representation of the object, or gain a higher specificity of the object if required.(Bar, 2003)

Recognizing Objects in Across Classes

The second factor in object recognition is being able to look across a class and generalize the object in that class. Generalization becomes incredibly useful when trying to determine what an unknown object is. Unknown objects are initially referenced to other objects in the assumed classification by their similarities and by their differences (Tarr & Vuong, 2002). It is still

unknown how the human brain assigns objects into classes, or how it creates the classes, to begin with (Grill-spector, 2008). Research into how people classify objects has developed the theory that individuals initially create basic levels, or classes of objects based on the most distinct features of the object, and not necessarily by what would traditionally be thought of as a class of objects. For example, one study found that when most people saw a picture of a pelican, they immediately called it a pelican-even though one would assume the class would be an even more basic level of “bird.” However, when people were shown a picture of a sparrow, they would call it a “bird” (Tarr & Vuong, 2002). With this knowledge of how individuals classify objects and recognize things like building infrastructure, it can be seen why individuals call items by what they recognize first and not necessarily what the object really is. A simple example of this would be calling an “*A19 incandescent soft white interior frosted 60 Watt 120VAC medium base bulb*”, what first class occurs to the individual “*light bulb*.” Being able to describe an object, and its unique visual qualities at the level where a CE craftsman can interpret what is being transmitted and how they can repair the problem brings in one more factor that must be addressed; the object specificity level.

Objects and Specificity Levels

Third most important for object recognition is the ability to recognize objects with varying amounts of specificity. From the previous section involving the example of bird specificity, and the ability to tell the difference between a sparrow and a pelican. It is theorized that there are several levels of object specificity starting with entry/basic all the way to subordinate. Determining to what level of object specificity is needed is a highly task-oriented process, which is dependent on the observer’s available time, and object information requirements (Tarr & Vuong, 2002).

A good example of the specificity process can be related to bears. If a bear is really close and growling, all that is needed is an entry/basic-level specificity with a short time requirement to gather the information needed prior to forming a reaction: see a bear, determine it is dangerous, and decide to run. Type, color, or even size is not terribly important at that moment. An example of high specificity is a wildlife biologist tracking bears safe on the top of a mountain; observing a bear at a great distance with plenty of time. In that situation specificity of visual information may be greater and include observing the size, shape, and color of the bear, so that accurate observation of the bear is accomplished. Directly related to CE, lack of experience starts to play a role. Individuals with little experience related to building infrastructure may only analyze an object enough to gain a basic-level specificity of the object, not realizing the necessary amount of information required to repair the object they are trying to submit. Knowing the level of specificity that is required to describe the object comes with experience and prior knowledge of the object.

Recognition Memory

Recognition of objects utilizes the theory of parallel processing which is a combination of top down, and bottom up processing (Bar, 2003; Berg & May, 1997; Shea, Biggs, & Matthen, 2013). The basis for parallel processing is that first top-down processing initiates when a partial image from the eye is projected onto the prefrontal cortex; upon image projection, your mind instantly reviews what most likely the object might be as an “initial guess” and determines if a reaction is needed. This initial guess is highly dependent on a person’s past experiences with the object. Top-down processing looks at the entire context, and expectation for the object then goes into memory to recall the representation as a whole (Bar & Ullman, 1996; Shea et al., 2013). After the “initial guess” enough of the image has been projected on the inferior temporal cortex that bottom-up processing takes over, and break up the unknown part(s) of the object into a

simple assortment of 36 geons (Biederman, 1987), and integrates the “initial guess” to try and create shortcuts to remembered object representations. Bottom-up processing continues until recognition is complete (Bar, 2003). Once processing has ended, and recognition has been achieved, the human mind can do whatever is necessary with the object. For example calling an object by its name or recognizing it as a functional object like a light switch and operating it (Shea et al., 2013).

Recognition memory and specificity levels brings in the experience aspect of visual recognition. Being able to recognize an object and call it by its technical definition to the level that a CE craftsman can know exactly what needs to be completed is nearly impossible with even simple systems or objects. With unusual objects that individuals do not work with on a frequent basis, or have any experience with, being able to visually recognize, and technically define an object to a useful level becomes nearly impossible. Descriptions of the object either becomes a description of its characteristic geons, a combination of stored representations, or completely attaching the wrong mental representation to an object and relaying the wrong information. Current CE Work Order submission systems rely on these mental representations, converted to a verbal/text string to deliver critical information. The only way to reduce this problem of inexperience is with a system that can relay exactly what an individual is seeing, to a CE Craftsmen that works with these objects on a daily basis, and can visually recognize exactly what the object is without question. Relaying this complex visual information can be completed through the use of smartphone photographic technology, utilizing the theory of media richness.

Media Richness

Quality information relayed to the CSU is the most important part of a work order submission. Without the packaging and transmission of work order information to CE, there would be no communication between customers and CE. The end result being that the base

would fall into deep disrepair. At a minimum, this packaged information must contain a description of the problem, geolocation of the problem, and a point of contact (Davis, 2013; Hasberry, 1991). How this information is packaged and delivered to convey high levels of object specificity is all contained within the theory of media richness. Media richness as defined by Daft and Lengel (1983) consisted of a mixture of four areas and final concept of whether the data was useful or not. The Four areas consist of feedback, communication channels utilized, source, and language (Bodensteiner, 1970; Holland et al., 1976; Rutter & Stephenson, 1979). Usefulness is the amount of meaning that the information delivers to reduce uncertainty, and equivocally (Daft, Lengel, & Trevino, 1986). First, the criteria of feedback will be discussed.

Feedback consists of how fast the communication medium allows for questions to be asked and the speed at which a response is returned.(Daft & Lengel, 1986) For this trait, instantaneous feedback is preferred. Both submission types, verbal and smartphone are considered to have instantaneous feedback. Verbal submission has instant verbal feedback from a CSU controller, while smartphone submission has the advantage of instant text and visual feedback from either the CSU controller or whomever the controller directs the conversation too. A big advantage of the CSU controller directing the conversation is the ability now for the SME being able to communicate directly with the customer to ensure the correct information about the problem is being collected. Additionally, the smartphone has greater capability being fully operational 24 hours a day, 7 days a week, while the verbal submission system is only fully operational for 8 hours a day Monday through Friday and emergency only status for the remainder of the time. With this, it can be seen that although both systems have what would be considered instantaneous feedback; smartphone feedback is preferred due to its expanded communication capability, and its 24-hour operational status. After feedback of the system, the next evaluation item is communication channels, and cues.

Utilized communication channels and multiple cues were developed by Daft and Lengel off of several studies with the first being from Rutter and Stephenson. It determined that depending on the media type; there was a drastic change in the available variety of social cues that human use to communicate with one another. These cues include “physical presence, voice inflection, high context, body gestures, words, numbers, and graphics symbols” (Daft & Griffin, 1983; Rutter & Stephenson, 1979).

Additionally, Bodensteiner in an earlier study of communication references channels defined by the type of media used such as face to face, or written media. These media’s that Bodensteiner classified as channels, Daft and Lengel reclassified them as mediums; with each medium having one to many channels, for instance, audio, limited visual(text), and visual (Bodensteiner, 1970; Daft & Griffin, 1983).

Reclassification of the mediums into multiple channels work well with emerging technologies, which have the capability of containing many channels that were not possible at the time the original research was being conducted. For the verbal process, a phone call which contains 1 channel of audio medium, is converted during the conversation to 1 channel written, in personal form, by the CSU controller during the submission, which reduces the richness of the original message. This written text is then sent to the craftsmen for completion. Smartphone work order submission consists of two channels, 1 visual, and 1 written. These submissions remain unchanged through processing, with the CSU controller potentially only adding additional information for the craftsmen. Outside the scope of this study, the addition of audio, and video submission channels are possible with current commercial smartphone mobile application technologies. Combined with the channel is the source of the information which relates to the nature of the information.

Source was originally defined as whether the communication is personal or impersonal in nature to the receiving individual, however, in Daft and Lengel's 1986 study this term was changed to personal focus.(Daft & Griffin, 1983; Daft et al., 1986). Its purpose was to better describe the value of information that contains not only personal feelings and emotions, but also a confirmation of the receiver's frame of reference, needs, and current situation. An example of impersonal communication would be unspecific, unaddressed media, like junk mail, or a bulletin board. In contrast, personnel communication could include memos, written letters to an individual, or in CE's case a work order given to a specific craftsman (Daft et al., 1986). Within both the verbal and smartphone systems the communication is personal, as it is geared toward the craftsmen specifically. How this information is presented, and how it is interpreted is largely due to the language used to code the information before transmission.

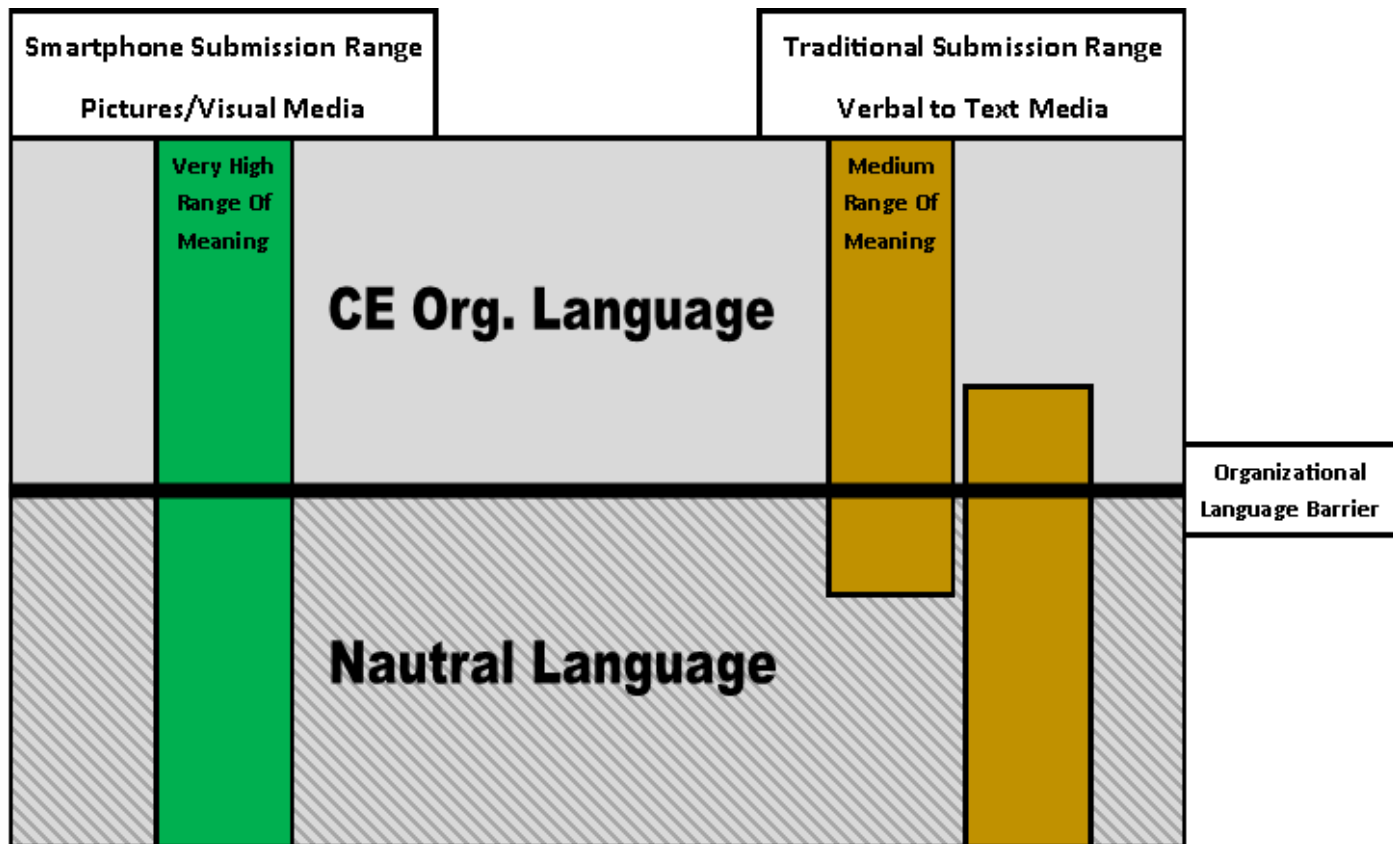
Language is the method of coding information in a way that is mutually understandable between the sender and the receiver and is measured by its "range of meaning that can be conveyed with language symbols" (Daft et al., 1986). Bodensteiner in 1970 identified two main capabilities to be used when evaluating a channel range of meaning for richness with language. First was the ability for the channel to communicate technical/mathematical information, and second was true meaning.(Bodensteiner, 1970) Technical/mathematical information being how the channels communicate symbols to include words/numbers, the speed of transmission, technical capabilities, noise, and mathematical capabilities not associated with the meaning. Within the true meaning capability, is feedback, which for the purpose of this study has been separated out to align with the Daft and Lengel information richness theory. Additionally, true meaning looks at the capability of the channel to allow the separation of unintended meaning, and potential intended meaning, as well as the ability for the channel to obtain a perfect correspondence between the sender and the receiver (Bodensteiner, 1970).

Bodensteiner's research confirms research that suggests natural language does a much better job of conveying broad concepts than does purely numbers while the use of numbers produces very exact results greatly reducing uncertainty and equivocality when a simple task is at hand.(Daft & Griffin, 1983) Although the process of work order submission uses what would be classified as natural language, within Civil Engineering (CE) there exists an entire subset of natural language that to a person on the outside of the organization it would be potentially unintelligible. This difference in language is due to the complexity of modern CE systems, and the social structure of the CE career field. Many career fields have this phenomenon of "organizational language" that would likely be considered a natural language, but outside of the social group it would almost be completely unintelligible; how can such a large language gap exist when using the same English language?

According to Roger Evered, his 1980 study found that within a common conversation: while only 23 words comprise of 50% of any conversation, over 1000 words comprise 99% of standard language usage, with 3000 words being used on a regular basis (Evered, 1980; Mathews, 1951; McKnight, 1923; Pei, 1966). He theorized that with such a narrow region of words being used the only way that miscommunications occurred were as a result of the set of 1000 words being related to a specialized activity. These activities could be related to certain sub-communities; his study specifically focused on the Navy as a community. He concluded this was a result of two things; that the individuals within the organization communicated with one another in their organization more than with outside entities, and that the organization tended to adapt their vocabulary to make themselves more cohesive, efficient, and productive.(Evered, 1980; Pei, 1966) Finally, he concluded that organizations created "In" words, to differentiate the organization from others, for social status, and for belongingness within the group.(Evered, 1980). CE is a prime example of this type of an organization that has its own language.

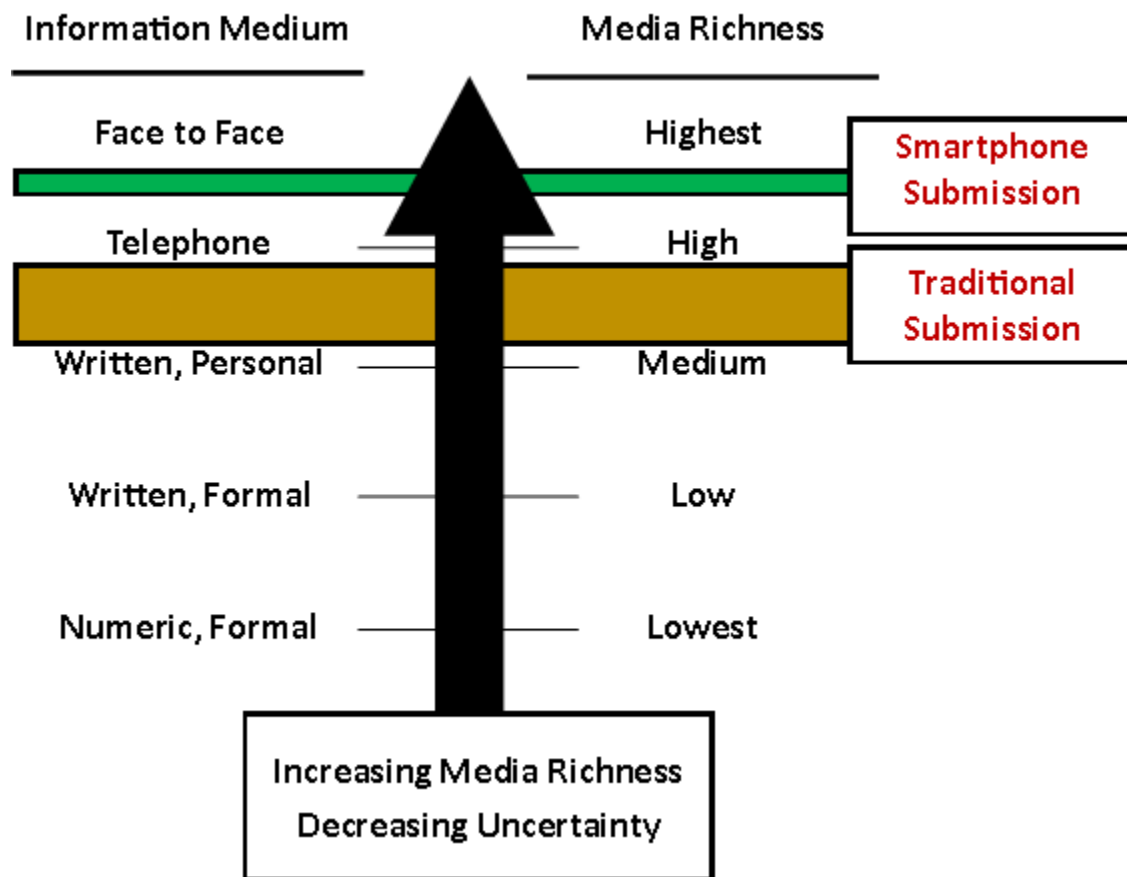
Language is one of the main hurdles for submitting a CE work order. Customers having limited facility system visual recognition experience, coupled with a lack of being able to communicate in a verbal/text-based language that is somewhat unique to CE, have a hard time communicating to CE what is wrong with their facility, or what they need help with. Smartphones provide a key to this language barrier, by providing a mechanism that allows both sides to understand each other's language. By utilizing pictures as a visual channel, customers can take a picture of a broken item, and catch all of the information needed for visual symbol transmission, so that a craftsman can perform visual recognition. It compensates for the customer's lack of CE language knowledge, by capturing all visual information possible and transmitting it directly to an individual that knows the language fluently. Verbal submission utilizes the CSU controllers as "translators" to try and ensure that the work orders being transmitted to the craftsmen are in CE language that they can understand enough to complete the task at hand. The effect of language range and media richness associated with submission type is shown in Figure 1. Figure 1 was a combination of information from the works of Daft and Lengel (1983), and Roger Everd (1980).

Figure 1: Media Type and Range of Language Meaning



Combined together the four components of media richness; feedback, communication channels utilized, source, and language, provide the ability to grade the quality of information that flows through an organization from high to low.(Daft et al., 1986) When combined certain media mediums and even sub medium types can be generalized from very high, to low levels of media richness. See figure 2 to see how the study's traditional submission which is largely verbal and text, compare to the richness provided by the smartphone mobile application. Figure 2 was an adaptation of Daft, Lengel, and Trevino (1986), Figure 1 on page 26 of their report, The Relationship Among Message Equivocality, Media Selection, and Manager Performance: Implications for Information Support Systems

Figure 2: Media Types and Corresponding Media Richness



One last thing to consider with media richness is that information is only useful as long as it reduces uncertainty and equivocality. The amount of information actually transmitted can only be determined by the level of uncertainty, and equivocally that is reduced by the information.(Bodensteiner, 1970)

Uncertainty and equivocality address two different areas of usefulness. Uncertainty addresses the lack of information required to make an informed decision, while equivocality highlights the problem of ambiguity associated with many, and sometimes conflicting analyses about the same set of information.(Daft et al., 1986) Media richness allows for a reduction in these two areas providing a much higher quality level of information.

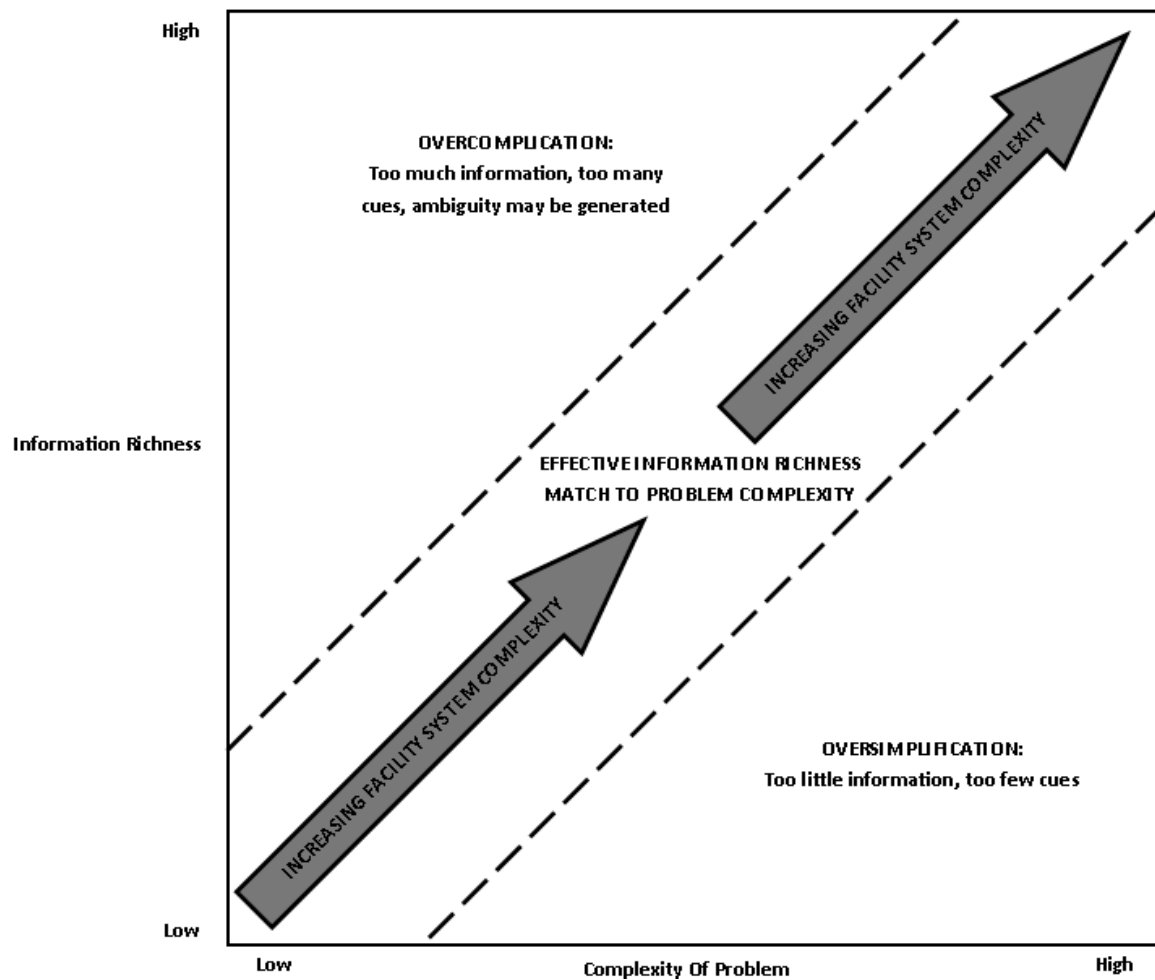
Daft and Lengel came the conclusion that for uncertainty reduction, as the amount of information increases the level of uncertainty decreases. When an organization faces a high level of uncertainty, its response is to utilize currently available information resources or acquire additional data to analyze, in pursuit of reducing uncertainty. Consequently, the results are the development of data driven answers with less risk from uncertainty (Daft et al., 1986). Galbraith noted that “Uncertainty is the difference between the amount of information required to perform the task and the amount of information already possessed by the organization”(Galbraith, 1974). While having more information typically equates to a reduction in uncertainty, with equivocality managers don’t even know what questions need to be asked to define solutions.

Equivocality is often associated with emotionally laden subjective messages, points of view that don’t align with others, ambiguity with the topic, or when determining what constitutes relevant information; all of which lead to misinterpretation (Kriebel & Strong, 1984; Mintzberg, Raisinghani, & Theoret, 1976). When this situation occurs, organizations tend to not seek out data for the solutions, instead they use experience, exchange subjective views, then define the problem and create a solution, instead of looking to external information sources outside of the organization, even if limited to develop a solution (Daft & Griffin, 1983). To overcome equivocality, a shared meaning of the information must first be established. Then by combining all options, to include external data and settling differences the problem can be better defined, and a solution reached (Daft et al., 1986). In conclusion, Daft and Lengel realized that although more information could solve the problem of uncertainty, they found that many times equivocality was much harder to solve than just adding more external information and analysis. An Equivocal solution requires not only external data but “hunches, discussion, and social support,” as well (Daft et al., 1986; Mintzberg et al., 1976).

To overcome equivocality, a shared meaning of the information must first be established (Daft et al., 1986). Most problems faced by CE are of an uncertainty nature, as they have an objective solution, that can be solved and made clear, given enough information that is not conflicting. While situations do arise in CE that are ambiguous and present problems of equivocality which cannot be solved with larger amounts of information. these situations will not be examined in this study as they are infrequent within CE. During standard operations, equivocal situations would be handled by CE operations to resolve remaining ambiguity with a problem to find a solution.

This concept of uncertainty reduction is where the term information usefulness was developed from to describe the amount of uncertainty, and equivocality reduction accomplished by the work order submissions to the CE craftsmen. The amount of uncertainty reduction and many times equivocality reduction can be directly related to media richness and the complexity of the decision that needs to be made. As a result, high richness channels have the ability to provide insight and rapid understanding to complex problems (Daft et al., 1986). In the case of a CE craftsman, the complexity of the decision that needs to be made is the complexity of the repair or diagnosis of the facility system. Created to explain the richness of information required to make a decision, Figure 3, shows the importance of matching the correct richness information to the decision that needs to be made. Low complexity being simple decisions, and high being complex decisions, adapted from Daft and Griffin (1983), *Information Richness: A New Approach to Managerial Behavior and Organization Design*, Figure 3. With building systems becoming more and more complex, the area of the graph where overcomplication may occur due to high media richness becomes less and less of a possibility.

Figure 3: Information Richness Needed for Corresponding Complexity



Conclusion

Throughout Chapter 2 several applicable areas were researched to develop testing methods for verification of a submission systems effectiveness. These relevant areas involved geolocation, visual recognition, and media richness. Combinations of the different areas resulted in the finalization of the study's hypothesis, as well as the methods used to verify them. Of interest to the study first was the subject of geolocation and its relation to the submission of a successful work order.

Geolocation is the ability to not only report a specific geographic location but also the ability to relocate the location. It is one of the first requirements of a work order, and without it, CE craftsmen could never respond to repair the problem. Investigating 32-1001 series base level facility operating manuals show that traditional submission systems only allow average Airmen to utilize verbal submission. This verbal submission is reduced to a short text string by the CE controller. With such little capability to describe a location certain scenarios result in the complete miscommunication of geolocation. This is often an issue when facility infrastructure is placed in a linear, or grid pattern. Individuals have a hard time geographically describing just one item in the pattern (Golledge et al., 2000). Additionally, issues arise when individuals have no ability to describe their location, or their perceived location is different from their actual location (Chang & Antes, 1987; Thorndyke & Hayes-Roth, 1980). These problems can be mitigated through the use of smartphones enabled with GPS. Quick and accurate geolocations can be established with minimal knowledge, or effort on the individual trying to determine their location (Maguire et al., 2006; Neyfakh, 2013; Rebello, 2011; William J. Hughes Technical Center, 2016). After the individual has established their location, recognizing the object becomes necessary to report it.

Visual recognition is an important first step in developing the description that will be sent to CE with the work order submission. Being able to visually recognize an object, and describe it is the result of several factors. First of the factors is an individual's past experiences with the object that is being described. Past experiences build visual representations of objects, that a person remembers, and recalls when they see the objects again. Representations of the object not only consist of a remembered image, they also carry additional information about the object, like its function, and name. If the individual cannot determine the object as a whole, they break down the object into rough classes of objects they remember, and geometric shapes. Utilizing these

representations based off of past experiences enables individuals to visually recognize the object, and mentally prepare a description to be transmitted (Bar, 2003; Bar & Ullman, 1996; Shea et al., 2013). Without experience with an object, individuals can only relay remembered representations that resemble the object and can lead to possible work order duplication. Mitigating this object experience can only occur in limited ways with facility infrastructure. One way is to educate all individuals to the visual recognition level of an expert, which isn't practical. Another way is to enable experts so that they can see what the individual is seeing, and perform the visual recognition themselves without having to be there. Over an audio based media channel, this capability isn't possible. However, with the expanded communication ability of a smartphone, transmission of visual information become possible.

Allowing an expert to see exactly what the customer is seeing is highly valuable to CE. How valuable this visual information is compared to audio information, can be measured through the theory of media richness. Media richness represents the last portion of work order submission, the transmission of data to CE, for eventual use by CE craftsmen. Underlying media richness theory is the concept that information is only useful as long as it reduces uncertainty for the receiver (Daft & Griffin, 1983; Daft & Lengel, 1986; Galbraith, 1974). CE craftsmen being the eventual receivers of information, their uncertainty exists in a problems description, and geolocation. Therefore, only CE craftsmen can determine the usefulness of information submitted. Usefulness of information has one more facet, and that is what organizational language the information is in. Organizations and groups of specialties have their own unique organizational languages as a result of constant internal communication, and adaptation for efficiency (Evered, 1980; Pei, 1966). CE customers have a hard time with this organizational language, which presents itself as a language barrier between the customer and CE. Customers for CE are typically outside of the organization and have limited facility diagnostic experience.

When a problem arises, inexperienced customers are forced to communicate with CE in a verbal/text-based language that is somewhat unique to CE. With such a limited communication channel, they have a hard time communicating to CE their problem, resulting in frustrations on both ends of the communication. Smartphones provide a key to increasing information usefulness and mitigating the language barrier, by providing a mechanism that allows both sides to understand each other's language. By utilizing the visual channel enabled by smartphones to send live images, customers can transmit all of the information needed to CE craftsmen. Upon receiving the transmission, CE craftsman can perform visual recognition, and reduce uncertainty about the problem.

This study is designed to validate that smartphone technology is capable of overcoming the obstacles of geolocation, duplication, experience, and organizational language. Additionally, proving that smartphone-based work order submission systems, deliver more overall useful information than traditional submission systems. Validation will be accomplished by conducting a real-world test to prove three hypotheses. First: Smartphone-based mobile work order submission applications when utilized by any individual, will submit information at a significantly greater usefulness than when using the traditional verbal based submission system. Second: When using the smartphone-based mobile work order submission system, any individual regardless of background will submit useful information at an equal or greater level than individuals within the CE organization. Third: Regardless of being a self-perceived facility expert, or novice, a smartphone-based work order submission system will enable all individuals to submit information at the level of an expert utilizing the same system. This increase in the usefulness of information being transmitted to craftsmen would have the immediate result of reducing communication errors, improving the site picture, and reducing travel, which would directly translate to the Air Force saving time and money.

III. Methodology

Introduction

The literature review indicated a lack of previous studies that tested whether a smartphone based work order generation system application relayed any more useable information to a craftsman than a traditional work order generation system. As a result, for this study, a new testing method was developed to evaluate the specific type of information transfer that occurs between a customer and a craftsman. The new method is unique in that it not only measured the value of information usefulness, it also analyzed thousands of historical work orders to recreate realistic testing scenarios of the most common work orders found on a base. After selection of the work order scenarios (infrastructure maintenance issues), an experiment was developed where subjects from all career fields were lead through a sequence of scenarios (experiment course) in which the subjects were required to submit work orders as they encountered a maintenance issue.

Post course walk through; subject matter experts (SME) analyzed each maintenance issue located on the course to determine what information would be required to submit a fully sufficient work order. Ideally, by providing the correct amount of useful information to CE craftsmen, this would help in preventing craftsmen from having to proceed to a job site for a purely diagnostic run. Instead, the craftsman could proceed to the site with a solution to the problem thus eliminating a trip. After determining what data SME CE craftsmen considered useful information and what was either unnecessary or is inadequate, subject results from the experiment were scored to determine the usefulness of the information for a work order (overall usefulness ratio) and accuracy of the description (description usefulness ratio), as determined by what SME craftsmen considered to be required for each. Statistical analysis was then completed on the scenarios overall usefulness ratio and description usefulness ratio to determine the

differences between the two systems . The first step was to determine what are the most common work orders on an Air Force Base.

Work Order Scenario Selection

It was determined that in order to develop sound experiment scenarios (simulated or actual maintenance issues), it was required to determine what are the most common types of maintenance issues found on Air Force Bases. Determining the scenarios consisted of two steps. First data was taken from six US bases that had traditional shops well represented; Dover AFB, Dyess AFB, Hurlburt AFB, Langley AFB, Robbins AFB, and Wright-Patterson AFB. Data was broken down by shop that completed the work to create a theoretical frequency of shop usage. For example, approximately 22.9% of all work orders are sent to the structures shop. After initial work order analysis, Dover AFB was chosen as the base for advanced word frequency analysis to determine what keywords were used the most to describe the work orders. Dover AFB was chosen for advanced analysis because it contained the cleanest data sets, and had very distinct shop coding. See Figure 4 for the base and shop work order breakdown, also see Appendix B for a larger copy.

Figure 4: Work Order Scenario/Shop Counts

		Base WO Counts							
Shop	IWIMS Shop Code	Dover AFB	Dyess AFB	Hurlburt AFB	Langley AFB	Robbins AFB	Wright-Patt AFB	Sub-Total	% Of Work Orders
Structural	CA/PC	2340	1630	2132	2357	3141	5531	17131	22.9%
Electrical	IT	1411	1339	1505	1745	2875	4142	13017	17.4%
HVAC	WW	1772	1885	2359	2590	4189	5430	18225	24.4%
Water	EC	1643	2224	1539	2315	1352	4307	13380	17.9%
Entamology	LF	526	150	470	420	1103	788	3457	4.6%
Heavy	PX	476	227	313	347	584	890	2837	3.8%
Alarms	ET	178	282	991	553	1647	1965	5616	7.5%
PowerPro	OX	74	39	70	144	154	139	620	0.8%
Sweeper	EO	3	3	0	2	0	498	506	0.7%
Water Plant	HZ	0	0	0	0	21	0	21	0.0%
Base SubTotal		8423	7779	9379	10473	15066	23690	74810	

Advanced work order word analysis was utilized to determine how to create the different scenarios. Work order descriptions were broken up by the top 4 shops which consisted of approximately 83% of all work orders. Descriptions by shop then were broken into their stem words. For instance, running would be converted into the stem word of run. Additionally, punctuation was removed, numbers were removed, all common English words not descriptive were removed (i.e. the, too, it, etc.), and finally common non-descriptive CE words were removed. Please see Appendix I for a complete list of words removed from the dataset. After the descriptions had been cleaned, the remaining words were put into a CSV format, consisting of the words, and the frequency of their use. Once created, the list was sorted from most to least common used. Most common words used more than 10 times were then again paired with the list of work order descriptions associated with the shop. By doing this, the occurrence of the most common words associated with the shop could be counted as the frequency of most common words within individual work order descriptions. Work orders could then be sorted by times that a most common word was used in the description; the higher the occurrence, the more relevant the work order would be in context.

To eliminate long descriptions being indicated as more relevant, the largest amount of characters allowed in each description was 70 characters. The reasoning behind the need for context is that the word count is a good indicator of items of interest, but when paired with occurrence in a work order description, it gives the context on how the items are all related. More information will be given in the analysis section of this paper, but for a quick example with electrical, a few of the keywords found were: light, emeg, and exit. After analysis, the top 20 words for the top four shops and the top 40 work order descriptions with the highest frequency of common words were chosen. With this information finalized, the Air Force Institute of Technology(AFIT) campus was searched using initially existing work orders provided by the

facility manager and then from researcher observations to create work order scenarios which could be incorporated in the planned experiment.

Determining which work orders to use in the creation of scenarios started with the initial matching of an existing work order to the context of the top 40 work order descriptions. After matching context, frequently used words of the most common work orders were tied into the scenario. An example of this tie in would be in the structures shop; there were many of the top 40 work orders that dealt with a door experiencing a malfunction of some type. Door and lock appeared frequently within the top 20 words. Using this information, a door was found that was experiencing a malfunction. Visual inspection indicated the malfunction was a result of the latching system. Contextually the door work order met a couple of the top 40 work order descriptions for structures, and it also was experiencing a failure that dealt with several of the top 20 words. Since the door experiencing a latching fault met these criteria of having a high chance occurring in the real world, it was chosen as one of the potential work order scenarios to be used in the experiment. In all, 29 scenarios were discovered within the AFIT complex.

Utilizing the list of work order scenarios, a circular route through many different facilities was created. Establishment of the route through the different areas was to facilitate randomization of testing direction, independent testing of two individuals at once, and to remove the test subjects from their normal environment at AFIT. Moving the subjects through different areas of AFIT was an attempt to standardize the lack of spatial knowledge that subjects had for the area. A lack of spatial knowledge results in the subjects being disoriented and forces subjects to observe their surroundings to determine their location. Additionally, exposing the subjects to unfamiliar surroundings reduces the likelihood of subjects having previous knowledge of the work order scenarios being used for testing. After creation of the route, a pilot test of the course was conducted to verify that it would work for the experiment.

Testing

After the careful selection of the different work order scenarios, the creation of the smartphone mobile application was necessary along with a standardized verbal capture system. Both tools were created to gather the three main items required for a CE work order; point of contact, location, and description of the problem. First, the smartphone-based mobile application was created to imitate the commercial version of the application and modified so the test subject could only enter subject number, location, and one descriptive photograph. A field for a descriptive phrase to go along with the photo for additional information was provided. After entering all the information the subject desired, they selected a submit button which would activate an automatic capture of the last known GPS location, time, and storage of the information. Once a subject selected submit there was no way for the individual to delete, or edit the submitted work order. No allowing editing of the work order prevented individuals from learning and realizing that as the test progressed they may be missing important information in their submissions.

A typical CE squadron has several operators that are standing by to take phone calls for work orders. To reduce the variability of a human asking questions and how the human perceives information verbally given over the phone, an automated recording and transcription system was adapted to be used in the experiment. A Google Voice voicemail account was set up and configured to ask the three questions required for work order submission. When called, the system would say *“Please answer the questions after the tone. What is your subject number? What is your location? And what is the infrastructure problem that you are trying to submit?”* After the tone, please answer the questions given by the message as if you were reporting an actual CE work order”. By automating the system, the questions were standardized for all test subjects, and every word uttered by a subject was recorded, as well as transcribed for easy

analysis. After creation of the smartphone mobile application, and the modification of the verbal system, a pilot study was conducted by the researchers.

To complete the pilot study, there were several tasks to accomplish. First, the researchers went through the course several times testing the system to standardize forms, ID technical difficulties, and write down what was to be said at each scenario. To view what was said at each location, the problem, as well as an image, please see Appendix C. Prior to testing random subjects, two experienced CE Airmen were guided through the course then asked for input on obvious irregularities, or overly ambiguous language. After their concerns had been addressed by modifications to scenario and script, a test subject pool was built and tested.

Subjects were requested from the AFIT student body and scheduled at their convenience from 0600-1900 to be lead through the course. To determine submission method and direction through the course, a randomized list was created that randomized both. Since the quantity of subjects for testing was unknown at the beginning of the experiment 50% randomization occurred in lots of 4 individuals at a time. By doing it this way, all tests within a window of four subjects would be a guaranteed of 50% method distribution and direction application to the subjects. To view the randomization list, please see Appendix E. Subjects were assigned their subject number and associated submission method in the order they were tested. By doing it this way, there was no way for any subject to know, or prepare for the method they would be using, or the direction they would be moving in. Randomization of direction through the course was utilized to detect a learning curve with either of the two submission methods if there was any.

Subjects came to the starting location and were read the standardized script by the researchers with a slight modification at the end to account for the difference between the two submission methods. At this time the test subjects also were given time to read and sign the informed consent form. At the end of each step, the test subjects were given the opportunity to

self-eliminate out of the experiment. To read a full version of the standardized script please see Appendix D. A full version of the informed consent form can be found in Appendix G. At this point, if the test subjects still wanted to proceed with the test they were led to either the first to a secure storage area to store any items that they didn't want to carry with them. This freed their hands to operate the submission tools and helped to reduce fatigue as the test progressed. Fatigue reduction was important given walking at a brisk pace; the course would still take approximately 45 minutes to complete. Efforts to reduce fatigue were important so that subjects wouldn't get fatigued then hurry through the remainder of the test.

After storage of personal items, subjects were guided toward their randomized direction start location either, forward direction 0, or reverse direction 1. Subjects were then shown the item, by pointing with the right pointer finger and circled with the finger in a clockwise direction, while being read the phrase for that scenario. After circling with a finger, and reading the phrase for the location, the researchers stood behind the subject and ceased communication with the subject unless a question was asked by the subject. If a question was asked that could not be found in the past experiment notes, it was written down along with the answer in the experiment notes. By writing down questions, and researcher responses, a standardized response could be given to test subjects. If any questions were asked that would affect a submission the subject was told that they could ask the question at the end of their run through the course. Once the subject was ready, they would submit the work order using the assigned submission method. After submission, the test subject was guided to the next location. This process was repeated for the remaining 29 scenarios.

During the course test information for the submission, methods were collected by computer for later analysis. Finally, test subjects completed a survey; survey questions were developed to answer questions researched in the literature review about potential factors as to

why some individuals did better submitting work orders than others. These questions were targeted at facility experience, and social circles to see if the effects of visual recognition and organizational language barrier played a role in the relay of useful information (Bar, 2003; Bar & Ullman, 1996; Berg & May, 1997; Evered, 1980; Pei, 1966; Shea et al., 2013). Additionally, several questions were asked that didn't have any literature review backing as to why they were chosen but were used from experience to isolate demographics of why some individuals were more effective at submission than others. To see the questionnaire, please see Appendix D. When subjects completed the survey they were then asked verbally if they had any questions or input about the experiment. Anytime there were items of interest spoken about experiment it was written down in the experiment notes for analysis later. Subjects were also given a notecard with the researcher's name, number, and E-Mail address on it so that if in the future concerns or inputs were thought of the individual could contact the researchers. At this time test subjects were also asked to not discuss the experiment with anyone to help avoid future test subjects having prior knowledge about the experiment.

Each subject was exposed to the same treatment for all runs of the course. After all of the subjects had gone through the course, and the test subject testing had been completed. Subject Matter Experts (SME) in their individual Civil Engineer crafts could be used to determine what qualified as useful information.

SME Data Coding

Post subject testing determination of what was useful information was incredibly important. Data gleaned from the SME's was in the form of keywords, and if pictures would help them in certain situations. Absolutely critical to this research was the ability to ensure that the technology was gathering what craftsmen would need to repair the problem. If the technology didn't reduce uncertainty or equivocality for the craftsmen, then the technology would be limited

in its ability for application to assist craftsmen. It, therefore, was essential for the craftsmen to code the usefulness of the information that they would potentially see from either of the submission processes. To gather this data was a combination of verbal interaction and questionnaire sheets specially developed for each scenario.

Starting the coding process SME's were given a short brief on the basics of the experiment, and what was needed from them. For the experiment briefing given to the SME's, please see Appendix H. It was important that the SME's understood how the system was to be implemented so that they could answer both sides of the questions. Questions were targeted at several areas of the experiment, and how to drive future submission research.

Questions were a combination of general and specialized questions to the following CE Shops Structural, Alarms, Heavy, Entomology, Water and Liquid Fuels Maintenance, Heating Ventilation and Air Conditioning, Electrical, and lastly Power Production. General questions were asked first to be followed by specialized questions. Questions were combined into packets that were labeled by shop and given out after the short briefing. These questions were developed to explore specific areas of interest associated with the mobile submission technology, as well as answering questions about technology in general.

General questions were targeted at how individuals interact with technology and people. Additionally, questions were asked to see what the craftsmen needed in the way of technology and information to make their jobs better. Specific to work orders they were asked if they would like some of the features that the mobile based technology would provide if implemented. After answering general questions, the craftsmen moved to specific scenario questions.

Specific questions were then asked based off of the actual scenarios and were split up by shop. Questions were developed to try and get a craftsman to think about the information, and steps necessary to diagnose the problem. First, if all they could do was get information from

someone about a broken item, and could not see it, what description and specificity level would be needed to repair the item. This question was designed to get a series of words for coding the outputs from test subjects. Second, they were asked about how good a location would have to be described to be able to quickly find the problem. Information about location accuracy is important to code the location data given by the test subjects. Next, the SME's were given a series of three photo's that were gathered from the mobile application, SME's were asked it would greatly increase their understanding and ability to repair the problem without going to the site. Finally, they were asked that beyond the picture what information the SME would need to repair the problem. This question was directed to be used to code the additional description given by some subjects when they were submitting work orders. It will also be used in conjunction with the first question to build the keywords used in coding the verbal submissions.

Effectiveness Analysis

Data was collected from the computers recording the experiments and analyzed against several areas to include the geolocation and description criteria developed from the SME coding, and duplication detection determining if work orders could be distinguished from one another, or similar items in the area. Within the scenarios, the collected data was used to primarily analyze object description, duplication detection, and geolocation accuracy between the two submission systems. Additionally, subjects were asked questions about their building diagnostic skill level, job within the Air Force, education level, age, rank, and gender. Responses to these questions were utilized when analyzing the data to determine if the application allows an inexperienced individual, or individuals outside of the CE organization to communicate at the level of an experienced individual using the traditional verbal based system.

Scoring and ratio calculation started with the subject's description being evaluated against what the SME's determined were required key pieces of information to know how to

repair the item. For each scenario, key pieces of information were compared against the verbal and mobile submission data from each subject. Data was evaluated with a binary value of pass(1)/fail(0). When the submission addressed the key data, it was evaluated as a pass; if not addressed then a failure was assigned. Geolocation data and duplication was converted to binary pass/fail criteria. Geolocation fails if the object was found to be outside of the limits listed by the SME, or contained vague location references. Duplication detection was categorized as; “pass” if the submission was clear enough to avoid mistaking similar items in the area as the item, or “fail” if the description was vague, and an individual could have mistaken similar items in the area as the target item for submission. To view grading sheets, with all key required useful information, please see Appendix A. After the initial grading, the description and overall ratio were calculated to evaluate the hypothesis. This grading and calculation is demonstrated, and fully evaluated in Chapter 4.

IV. Analysis and Results

Chapter Overview

Analysis of the two submission systems ultimately showed that smartphone-based mobile work order submission applications when utilized by any individual, regardless of expertise or AFSC, will deliver useful information to craftsmen at the same level, or higher, than CE personnel or facility experts using the current traditional submission system. This increase in the usefulness of information being transmitted to craftsmen would have the immediate result of reducing communication errors, improving the site picture, and reducing travel, which would directly translate to the Air Force saving time and money. Proving this hypothesis consisted of utilizing statistics to analyze and prove systematically that the information collected by smartphone-based mobile application users contained more useful information as predicted by media richness theory and visual recognition section of this study.

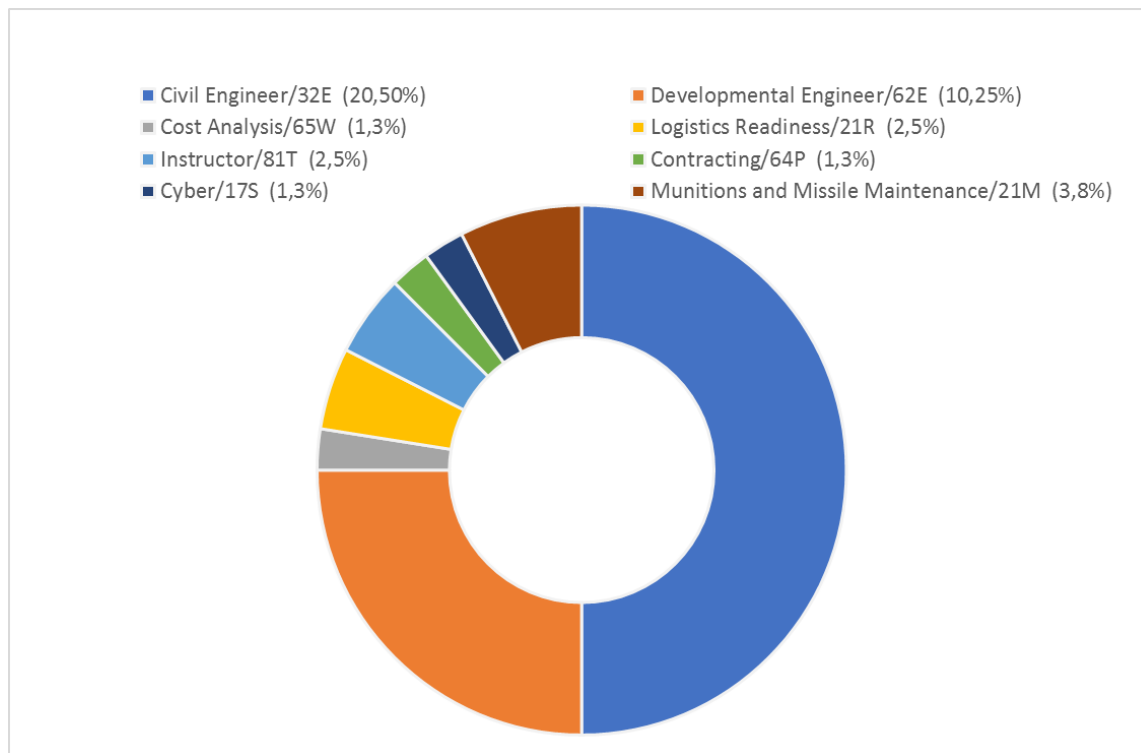
Proving systematically that the smartphone-based system worked better than the traditional verbal system started by calculating an overall information usefulness ratio, and description ratio of the information collected, and then examining which of the submission technologies possessed a higher ratio. Useful information is defined by the factors of geolocation, object description, and duplication detection as described in Chapter 2. Next, an assessment of the smartphone-based applications ability to mitigate organizational language barriers is examined. Additionally, to determine if the smartphone-based mobile application allowed individuals to communicate at the level of a perceived facility expert, the description ratio was examined by experience level to see if all levels of experience could communicate the same information. Finally, an analysis of geolocation accuracy and duplication detection was conducted to determine if the smartphone-based mobile application improved these metrics.

Information and Demographics Collected

Information on all test subjects was collected during the post-study questionnaire. To view the information collected on each subject, please see Appendix J. Demographic areas of particular interest to the study were, the AFSC/job skill/organization, self-perceived facility diagnostic expert, and education. Additionally, age, pay grade, and gender was collected to determine if these demographics had any effect on the collection of information by each system.

Initially, the AFSC of all participants were analyzed for an organizational distribution, to determine if there was a representative mix of organizational language that could be compared to the CE organization. This distribution is shown on Figure 5.

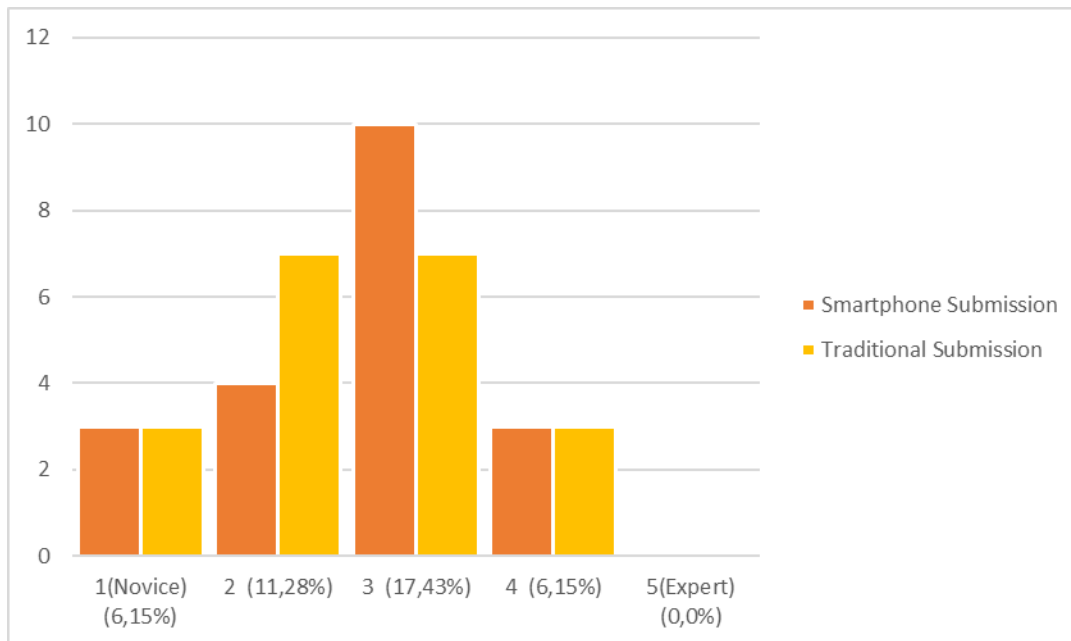
Figure 5: Test Subject AFSC/Job Skill/Organizational Distribution



From the distribution table and graph, it can be seen that there is a good distribution of AFSC's. With such a diverse distribution of organizational languages and a strong 50% of CE, a subset can be made that splits the subjects in half. By splitting the subjects into the groups of CE organization, or non-CE organization the ability for the smartphone-based application to communicate between organizational languages can be analyzed.

After analyzing for organizational language distribution, looking at the distribution of self-evaluated facility experts is required. This metric was selected by the test subjects as a self-evaluated value during the post-test questionnaire, administered at the end of the submission course. A goal of this metric was to get a mixture of high level, mid, and low-level diagnostic abilities, so that further analysis could be done on the system's ability to communicated between these levels, and ultimately if a novice could communicate information at the same level of an expert. The distribution of the subjects, by self-evaluated diagnostic ability, is in Figure 6.

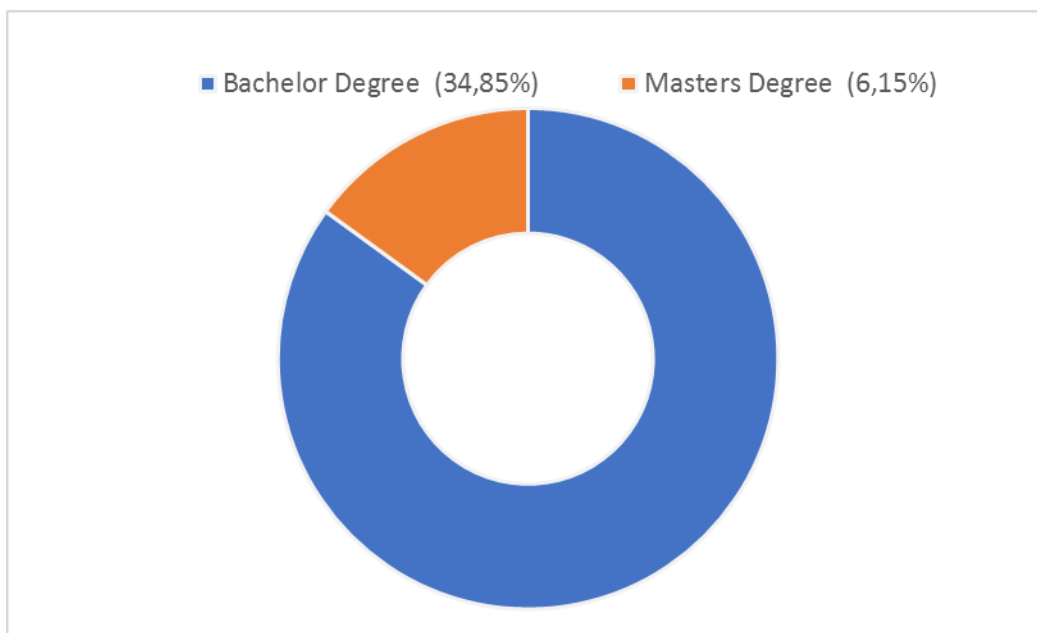
Figure 6: Test Subject Self-Perceived Facility Diagnostic Ability



As can be seen from Figure 6, the distribution diagnostic ability is well distributed for the test with 43% of the individuals being in the middle range. Additionally, the distributions of submission method are shown within the ability levels. Distribution indicates that within the ability levels, there were close to equal amounts test subjects utilizing each method. With the distribution of subjects utilizing each submission method nearly equal for all ability levels, determining if smartphones allow individuals regardless of experience level to communicate at the level of an expert is more credible, as all levels are close to being weighted equally.

Additionally, education levels of the test subjects were gathered to see if individuals with higher levels of education perform better, as they would theoretically have more knowledge, and potentially recognize, and be able to communicate more than an individual with less education. The distribution of education levels are in Figure 7.

Figure 7: Test Subject Education Level Distribution



As can be seen from the distribution in Figure 7 there was a majority of the test subjects holding bachelor degrees, with only 15% holding a master's degree. No test subjects had less than a college level education.

Additional demographics that were collected were age, pay grade, and gender. Figure 8, shows the age distribution of test subjects, Figure 9 lists the pay grade distribution of the test subjects, and finally Figure 10 lists the distribution of gender amongst the test subjects.

Figure 8: Test Subject Age Distribution

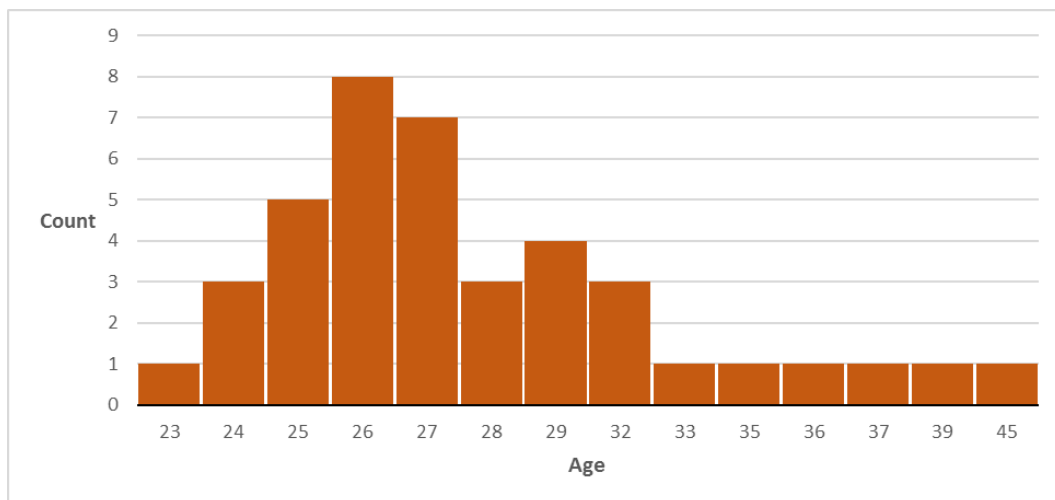


Figure 9: Test Subject Grade Distribution

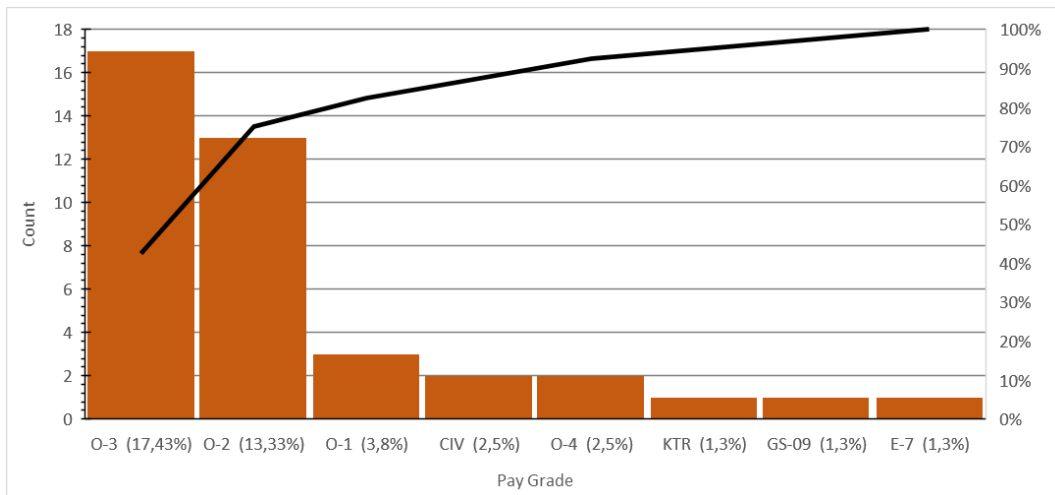
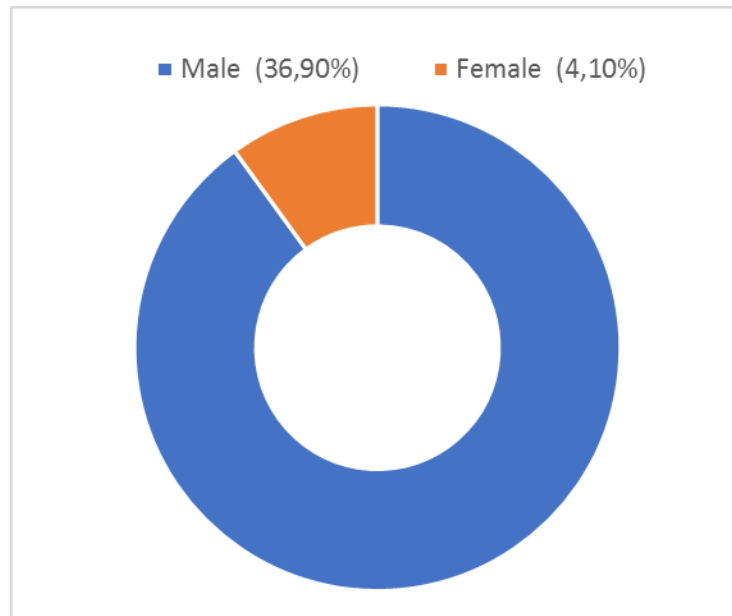


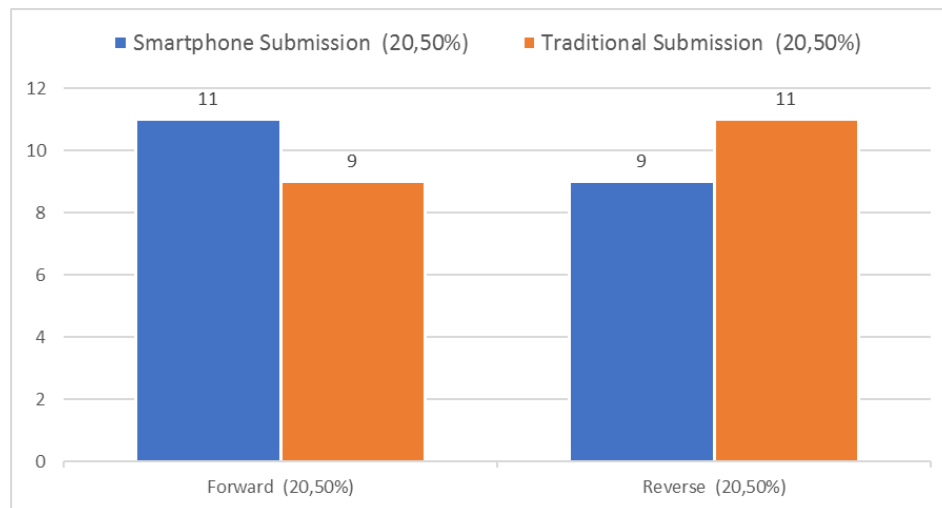
Figure 10: Test Subject Gender Distribution



Figures 7, 8, and 9 showcases the remaining distributions that were collected for the study. Subject test age had a max age of 45 and a minimum of 23 with a concentration of subjects at age 26. Pay grade was heavily skewed toward being comprised of 43% O-3's. Finally, males dominated the gender distribution with 90% of subjects being male. Gender will be analyzed later to determine if it has an effect on the overall usefulness ratio. Pay grade, and age could not be used effectively to determine if they affect the overall usefulness ratio, as the distribution of submission methods within the subsets are drastically varied. Age distribution skewed heavily toward older individuals being assigned smartphone-based submission, and younger individuals being assigned traditional submission. Pay grade distribution was skewed with a concentration of mobile users in the O-3 to O-2 band.

In addition to demographics, test methods and directions were collected to ensure an even distribution of smartphone/traditional submissions, and directional differences. Figure 11 shows the direction distribution and submission method distribution within the direction.

Figure 11: Test Subject Direction and Method Distribution



From the distribution shown in Figure 11, it can be shown that there is a small discrepancy with smartphone submission, and traditional submission when related to direction. Potential effects, like directionally related overall usefulness ratio differences, will be explored in later sections of this chapter.

Initial Work Order Submission Analysis and Ratio Calculation

Prior to validating the three hypotheses, all submitted data was first analyzed to determine its overall usefulness, and description ratio. Initial analysis consisted of first loading all submitted information into a worksheet customized for each scenario. Customization of the worksheet was dependent on the key data identified by CE craftsmen during SME data coding. Once loaded the individual key pieces of data, to include geolocation and duplication detection were graded on a pass-fail basis. Ending the analysis process was the calculation of ratios. Overall usefulness ratio was calculated by summing the description ratio score, geolocation score, and duplication detection score. This summed score was then divided to produce an equally weighted overall usefulness ratio of the information provided. Evaluation of smartphone-based submission and traditional submission effectiveness utilize this ratio for analysis, as it clearly

shows the usefulness of a submission. Description ratio is the summed description score divided by the maximum description score available. Mitigation of language barrier and facility diagnostic experience mitigation rely on this ratio for analysis. This particular ratio represents information that can be directly related to experience, and organizational language background. Where the overall usefulness ratio represents the additional factors of duplication, and geolocation which play little role in diagnostic experience, or language background. An example of initial work order analysis and ratio calculations for subject one at scenario 29 can be seen in Figure 12.

Figure 12: Initial Work Order Submission Analysis and Ratio Calculation

Test Subject Work Order Submission Data						
Subject Number	Scenario Number	Method (Mobile 1/Call In 0)	Short Scenario Description	Subject Reported Location	Smartphone Geolocation	Subject Description of Problem
1	29	1	Bad Light Fixture	Bldg 641	39.782963, -84.082127	Faulty light or ballast near rm 126, in corner by roll up door

Subject 1, Scenario Photo Submission



Continuation of Figure 12

Description Analysis								
Light Flickering	Strip w/Reflector Fixture Type	Size 4Ft 2Lamp	One/Many out	Voltage	Wattage	Bulb Shape	Bulb Base	Bulb Type
1	1	1	1	0	0	1	0	1

ADD'L Analysis		Caculations					
Geolocation Score	Duplication Score	Description Score	Score Sum	Max Overall Usefulness Score	Max Description Score	Overall Usefulness Ratio	Description Ratio
0	1	6	7	11	9	0.5555556	0.66666667

$$Description Ratio = \frac{Description Score}{Max Description Score}$$

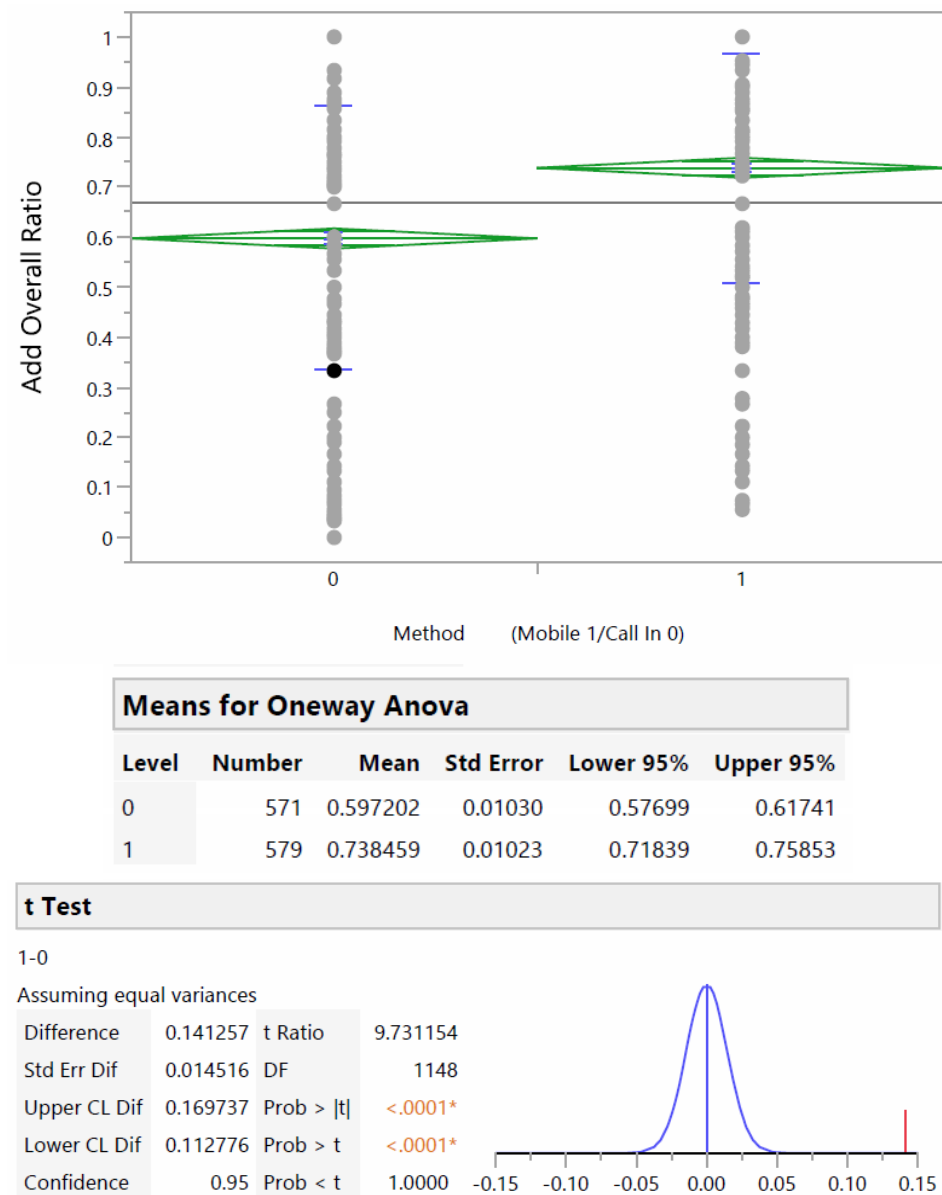
$$Overall Usefulness Ratio = \frac{Geolocation Score + Duplication Score + Description Ratio}{3}$$

Primary Submission Method Analysis

Determining whether smartphone-based mobile work order submission or a traditional verbal based work order submission enabled customers to submit more useful information was one of the primary purposes of this study. To measure the overall effectiveness of the submission methods, the overall usefulness ratio consisting of geolocation, duplication detection, and description will be analyzed using the statistical program JMP®.

Initially, an independent t-test was run on the data when split into the two groups of mobile submission, and traditional submission. Considering the samples to be independent, this test yielded the results listed in Figure 13.

Figure 13: Overall Ratio Analysis



From the analysis in Figure 13, it can be seen that there is a significant difference between the two methods ($t(1148) = 9.73$, $P < .05$) rejecting the null hypothesis; indicating the mobile submission is more capable of delivering useful information. The usefulness ratio mean

for the traditional method was 0.60 (sd = 0.26), and the mean on the smartphone method was 0.74 (sd = 0.23).

To verify these results normality and variance need to be tested. Sample failed for normality (Shapiro-Wilk W Test), but does pass variance(Levene), therefore the non-parametric Wilcoxon/Kruskal-Wallis Rank Sum test was utilized to verify results. Results from the test are outlined below in Figure 14.

Figure 14: Overall Ratio Non-Parametric Tests

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)								
Level	Count	Score Sum	Expected Score	Score Mean	(Mean-Mean0)/Std0			
0	571	272157	328611	476.631	-10.037			
1	579	389669	333215	673.003	10.037			
Nonparametric Comparisons For Each Pair Using Wilcoxon Method								
q*		Alpha						
1.95996		0.05						
Score Mean				Hodges-				
Level	- Level	Difference	Std Err Dif	Z	p-Value	Lehmann	Lower CL	Upper CL
1	0	196.3695	19.56401	10.03728	<.0001*	0.1333333	0.1111111	0.1555556

The Wilcoxon/Kruskal-Wallis Rank Sum test also determined that there was a significant difference between the two methods ($Z = 10.04$, $p < 0.05$). These tests confirmed that the smartphone-based mobile work order submission application does deliver more useful information; the question of its ability to mitigate organizational language barriers, and communicate at the level of an expert regardless of experience remained.

AFSC Submission Method Analysis

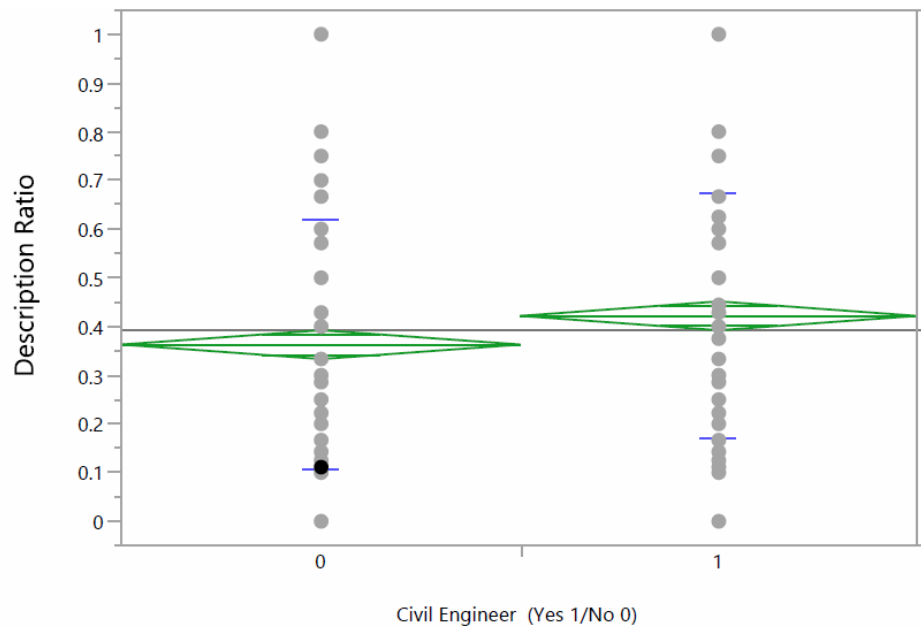
A second of the applications promising areas was to deliver more useful description information across the organizational language barrier. Focusing on description ratio of the object only was the focus for the next part of the analysis. The reasoning behind the focus on just

the description is that the ability of an individual to describe their location should be unhindered by organizational language, and would be more related to other situational factors. An analysis of geolocation and duplication detection between the two submission methods will be done later in Chapter 4.

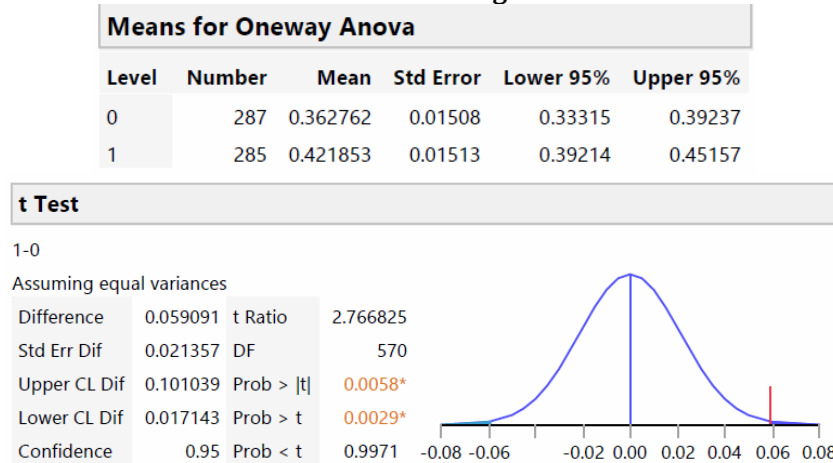
Analysis of how smartphone-based mobile work order submission applications mitigate the organizational language barrier started with the sub-setting of the two submission methods, so that within the subsets a comparison between individuals within the CE organization, and individuals outside of the CE organization can be made.

Traditional submission analysis was started by conducting an independent t-test on the group, with the consideration that the samples were independent. Results from the test are shown in Figure 15.

Figure 15: AFSC Comparison With Traditional Submission Method



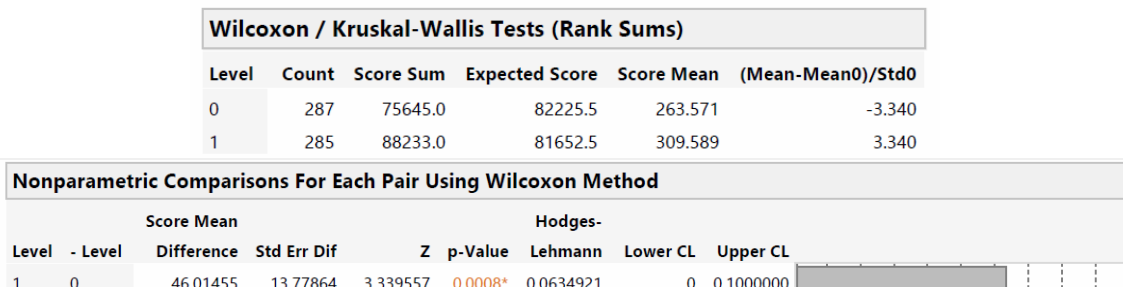
Continuation of Figure 15



From the analysis in Figure 15, it can be seen that there is a significant difference between the two methods ($t(570) = 2.77$, $P < .05$) rejecting the null hypothesis; strongly suggesting that there is a difference between organizations, indicating a language barrier when utilizing the traditional method which relies on a less rich verbal/text based system. The description ratio mean for the CE organization was 0.42 ($sd = 0.25$), and the mean for individuals outside of the CE organizations was 0.36 ($sd = 0.26$).

To verify the results, assumptions of normality and variance must be confirmed. Sample fails for normality (Shapiro-Wilk W Test) but does pass variance(Levene). Therefore the non-parametric Wilcoxon/Kruskal-Wallis Rank Sum test was utilized to verify results. Results are shown in Figure 16.

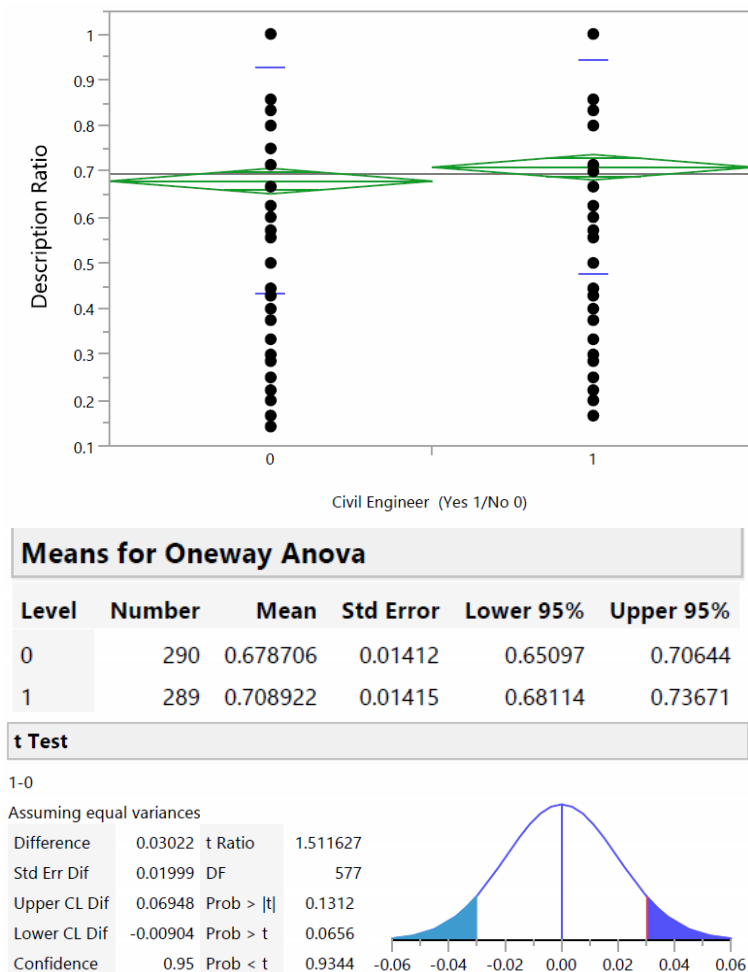
Figure 16: AFSC Comparison Traditional Submission Non-Parametric Tests



Non-parametric tests confirmed that there was a significant difference between the two organizational groupings ($Z = 3.34$, $p < 0.05$). This confirmation indicates that individuals in the CE organization do have a distinct advantage when submitting work orders using the traditional method over individuals in a different organization.

An analysis of the second subset was then accomplished to determine if smartphone-based mobile work order submission technology mitigated the CE organizational language barrier verified with the previous analysis. Results from this test are shown in Figure 17.

Figure 17: AFSC Comparison Smartphone Submission Method



From the analysis seen in Figure 17, it can be seen that there is no significant difference between the two methods ($t(577) = 1.51$, $P > 0.05$) failing to reject the null hypothesis; indicating that when utilizing the smartphone-based mobile work order submission technology, there is an effect of mitigating organizational language barriers. The description ratio mean for the CE organization was 0.71 ($sd = 0.23$), and the mean for individuals outside of the CE organization was 0.68 ($sd = 0.25$).

To verify results the assumptions of normality, and variance must be confirmed. Sample fails for normality (Shapiro-Wilk W Test), but does pass variance(Levene), therefore the non-parametric Wilcoxon/Kruskal-Wallis Rank Sum test was utilized to verify results. Results are shown in Figure 18.

Figure 18: AFSC Comparison Smartphone Submission Non-Parametric Tests

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)					
Level	Count	Score Sum	Expected Score	Score Mean	(Mean-Mean0)/Std0
0	290	81324.0	84100.0	280.428	-1.394
1	289	86586.0	83810.0	299.606	1.394

Nonparametric Comparisons For Each Pair Using Wilcoxon Method									
q*		Alpha							
1.95996		0.05							
Score Mean				Hodges-					
Level	- Level	Difference	Std Err Dif	Z	p-Value	Lehmann	Lower CL	Upper CL	
1	0	19.17450	13.75593	1.393908	0.1633	0	0	0.0476190	

Non-parametric tests confirmed that there was no significant difference between the two groups ($Z = 1.39$, $p > 0.05$). This confirmation proves that when individuals are utilizing the smartphone-based work order submission application, the language barrier is completely mitigated. Regardless of an individual being in CE or a different organization, the smartphone application allows every individual to communicate the same amount of description information, minimizing the effect of an organizational language barrier.

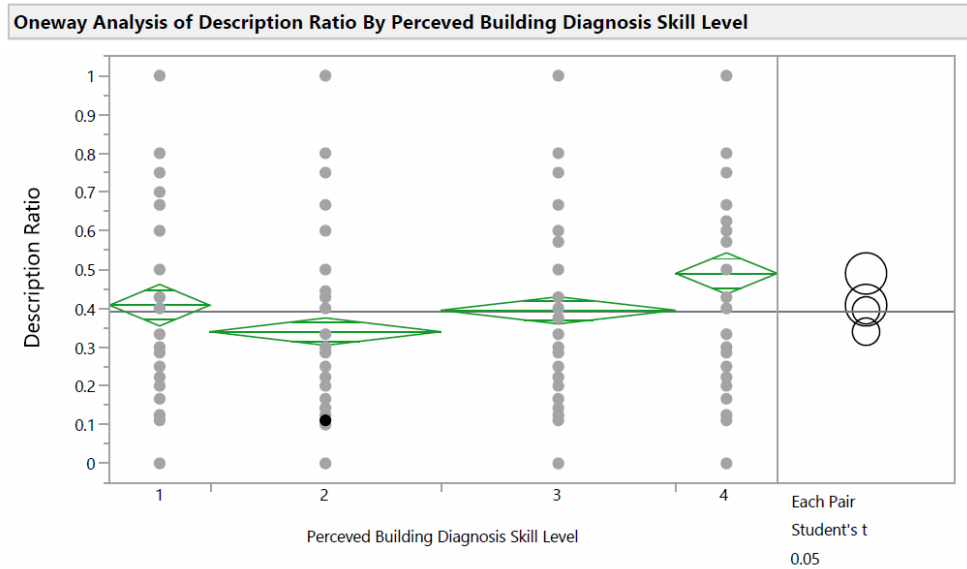
Self-Evaluated Diagnostic Ability Submission Method Analysis

After confirmation that there is an organizational barrier that was mitigated as a result of utilizing smartphone-based work order submission technology. Another area of interest is the technologies effects on the ability of individuals with different diagnostic ability to communicated the same amount of description information, as an expert. Reasons for looking at just the description ration with this particular portion of the test had two parts. One is that all individuals were considered to have the same ability with their assigned submission method, across all levels of diagnostic abilities. Second is description can be directly related to an individual's facility diagnostic skill level, where location and duplication are not necessarily related to an individual's ability to diagnose infrastructure, and more related to other factors. These factors will be explored later in Chapter 4.

Analysis of how smartphone-based applications allowed individuals of all different diagnostic abilities to communicate, started with the sub-setting of the two submission methods. Sub-setting of the methods allowed for an Analysis of Variance (ANOVA) to be completed on the diagnostic ratios between the five levels of self-evaluated diagnostic ability.

Traditional submission was the first subset of diagnostic ability to be analyzed through ANOVA. All of the samples within the different levels were considered to be independent. Results from the ANOVA test are shown in Figure 19.

Figure 19: Diagnostic Ability Comparison With Traditional Submission Method



Oneway Anova

Summary of Fit

Rsquare	0.037169
Adj Rsquare	0.032083
Root Mean Square Error	0.252721
Mean of Response	0.392204
Observations (or Sum Wgts)	572

Analysis of Variance

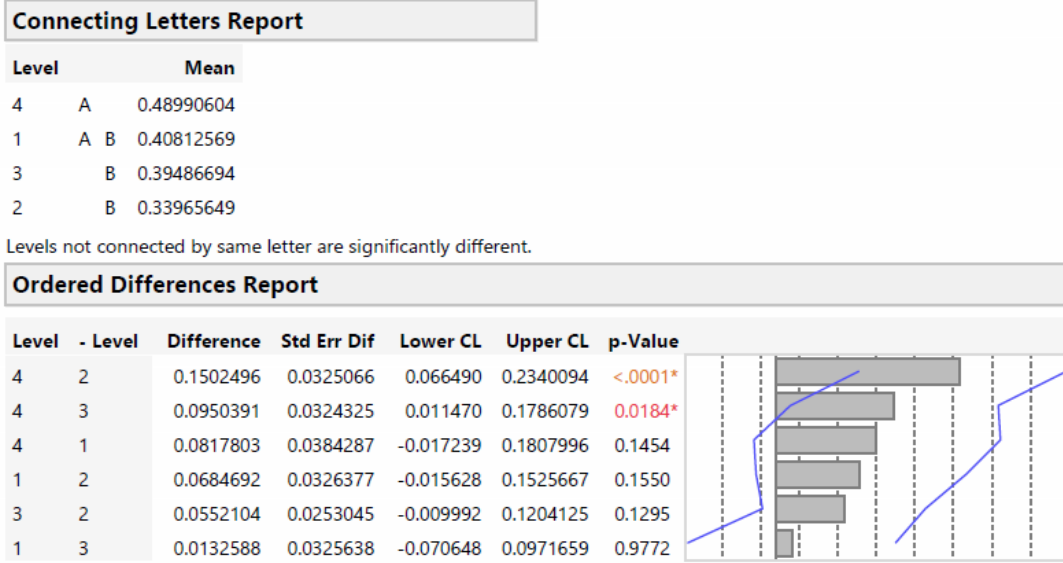
Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Perceived Building Diagnosis Skill Level	3	1.400427	0.466809	7.3090	<.0001*
Error	568	36.277081	0.063868		
C. Total	571	37.677508			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1	86	0.408126	0.02725	0.35460	0.46165
2	198	0.339656	0.01796	0.30438	0.37493
3	201	0.394867	0.01783	0.35985	0.42988
4	87	0.489906	0.02709	0.43669	0.54312

Std Error uses a pooled estimate of error variance

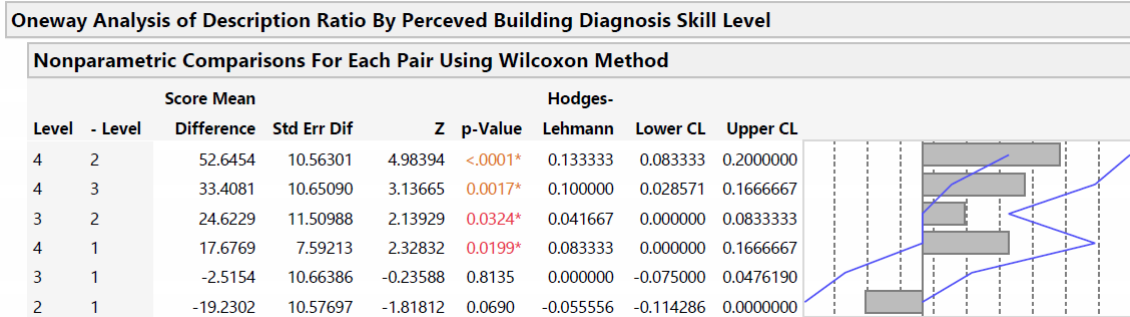
Continuation of Figure 19



A one-way ANOVA was used to compare the traditional submission description ratio means between the different self-evaluated facility diagnostic skill levels. These results are shown in Figure 19. A significant difference was found between the description ratio means($F(3,572) = 7.31, p < 0.05$). Tukey's HSD was utilized to determine the differences between the skill levels. Analysis showed that skill level 4 ($M = 0.49, sd = 0.25$) scored much higher than other levels, and was significantly different from levels 2 and 3. Skill level 1 ($M = 0.41, sd = 0.27$) wasn't significantly different from level 2 ($M = 0.34, sd = 0.23$), level 3 ($M = 0.39, sd = 0.26$), or level 4.

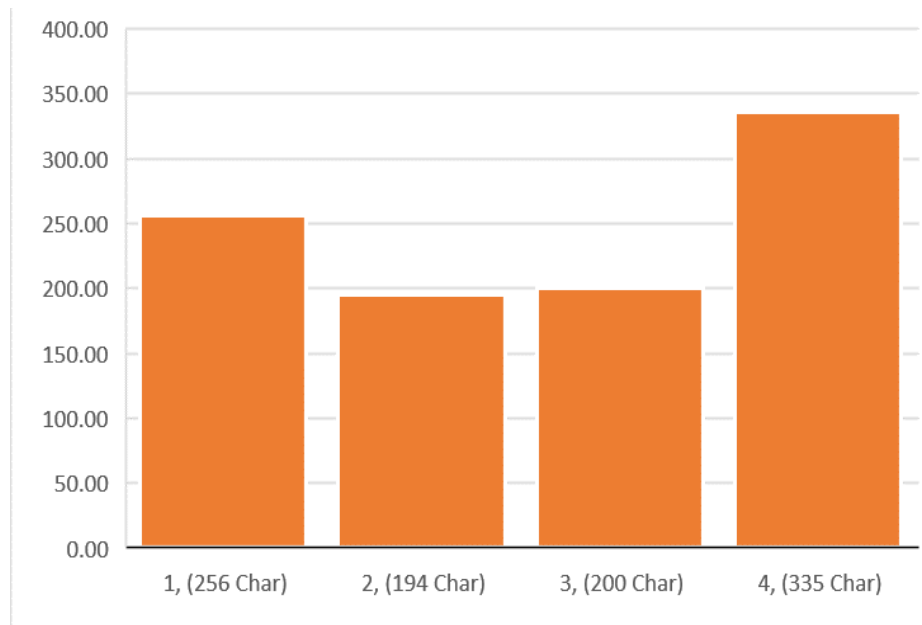
To verify results the assumptions of normality, and variance must be confirmed. Sample fails for normality (Shapiro-Wilk W Test), but does pass variance(Levene), therefore the non-parametric Wilcoxon/Kruskal-Wallis Rank Sum test was utilized to verify results. Results are shown in Figure 20.

Figure 20: Diagnostic Ability Comparison with Traditional Submission Method Non-Parametric Tests



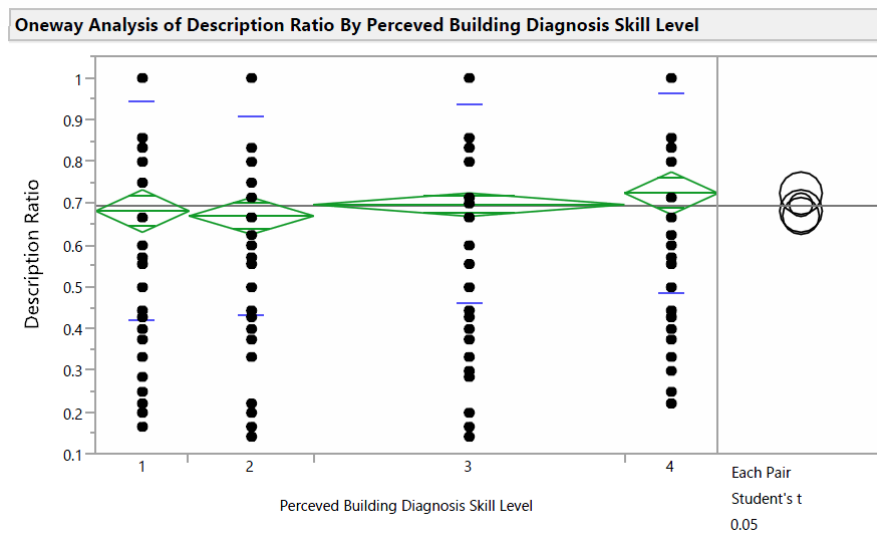
Non-Parametric pairwise comparison tests indicate the same trends as the ANOVA test. Exceptions to the ANOVA test are that levels 2 and 3, and 1 and 4 are shown as being significantly different. However, this significant difference is small, considering the significance of this test is $\alpha = 0.05$. This confirmation of results from the ANOVA test shows that the traditional method, utilizing a less rich verbal/text based system, is indeed dependent on the individuals self-evaluated facility diagnostic level. Individuals that indicated they were better at diagnosing facility problems did submit higher level description ratios at different levels in numeric order. Exception to this order was for level 1 which performed at a level 3, and 4. This phenomenon is most likely a result of individuals knowing that their skills at facility diagnosis were lacking. Once told the item to report they would make up for this lack of knowledge, by describing everything that they could visually recognize, or express similarities with objects they relate to. Many times, this verbalization of visual representations would end up conveying a key piece of information even if they didn't realize it. Potential confirmation of this theory can be seen in Figure 21, level 1 and 4 individuals used many more characters to describe the problem than levels 2 and 3. This suggests that they were describing, and transmitting much more information than expected.

Figure 21: Self-Evaluated Facility Expert Character Count



An analysis of the second subset was then accomplished to determine if smartphone-based mobile work order submission technology had the effect of allowing all levels of diagnostic abilities to communicate at the level of an expert. Results from this test are shown in Figure 22.

Figure 22: Diagnostic Ability Comparison With Smartphone Submission Method



Continuation of Figure 22

Oneway Anova

Summary of Fit

Rsquare	0.004831
Adj Rsquare	-0.00036
Root Mean Square Error	0.24081
Mean of Response	0.693788
Observations (or Sum Wgts)	579

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Perceived Building Diagnosis Skill Level	3	0.161879	0.053960	0.9305	0.4256
Error	575	33.343870	0.057989		
C. Total	578	33.505749			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1	87	0.682257	0.02582	0.63155	0.73297
2	116	0.670478	0.02236	0.62656	0.71439
3	289	0.697274	0.01417	0.66945	0.72510
4	87	0.724818	0.02582	0.67411	0.77553

Std Error uses a pooled estimate of error variance

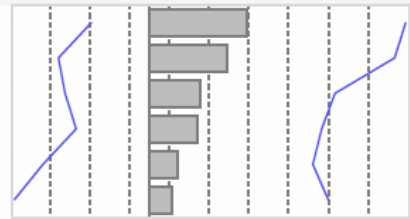
Connecting Letters Report

Level	Mean
4	A 0.72481755
3	A 0.69727441
1	A 0.68225689
2	A 0.67047756

Levels not connected by same letter are significantly different.

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
4	2	0.0543400	0.0341534	-0.033660	0.1423397	0.3845
4	1	0.0425607	0.0365115	-0.051515	0.1366363	0.6488
4	3	0.0275431	0.0294482	-0.048333	0.1034196	0.7859
3	2	0.0267969	0.0264682	-0.041401	0.0949948	0.7422
3	1	0.0150175	0.0294482	-0.060859	0.0908940	0.9567
1	2	0.0117793	0.0341534	-0.076220	0.0997791	0.9859



A one-way ANOVA was used to compare the smartphone-based submission description ratio means between the different self-evaluated facility diagnostic skill levels. These results are shown in Figure 22. No significant difference was found between the description ratio means ($F(3,579) = 0.93, p > 0.43$). Having no significant difference indicates that smartphone-based submission has a tremendous impact on allowing all diagnostic abilities to submit information at the same level as an expert. It can be seen from the values that there is still a relation to the level of ability, and ratio description transmitted. This relation to ability is relatively small between the levels when compared to traditional submission. Tukey's HSD was utilized to determine these differences between the skill levels. Analysis showed that skill level 1 had a mean ratio of 0.68 (sd = 0.26). Skill level 2 had a mean ratio of 0.67 (sd = 0.24). Skill level 3 had a mean ratio of 0.70 (sd=0.24). Finally, skill level 4 had a mean ratio of 0.72 (sd=0.24).

To confirm these findings verification of normality, and variance must be confirmed. Sample fails for normality (Shapiro-Wilk W Test), but does pass variance (Levene), therefore the non-parametric Wilcoxon/Kruskal-Wallis Rank Sum test was utilized to verify results. Results are shown in Figure 23.

Figure 23: Diagnostic Ability Comparison with Smartphone-Based Submission Method Non-Parametric Tests

Nonparametric Comparisons For Each Pair Using Wilcoxon Method									
q*		Alpha							
1.95996		0.05							
Level	- Level	Score Mean Difference	Std Err Dif	Z	p-Value	Hodges-Lehmann	Lower CL	Upper CL	
3	2	13.4581	12.74125	1.05626	0.2908	0.0000000	0.000000	0.0666667	
4	2	13.2256	8.23939	1.60516	0.1085	0.0285714	0.000000	0.1428571	
4	3	12.6066	13.13777	0.95957	0.3373	0.0000000	0.000000	0.0714286	
4	1	7.7241	7.53312	1.02536	0.3052	0.0000000	0.000000	0.1333333	
3	1	4.6060	13.15089	0.35024	0.7262	0.0000000	0.000000	0.0500000	
2	1	-3.6911	8.25379	-0.44720	0.6547	0.0000000	-0.069444	0.0285714	

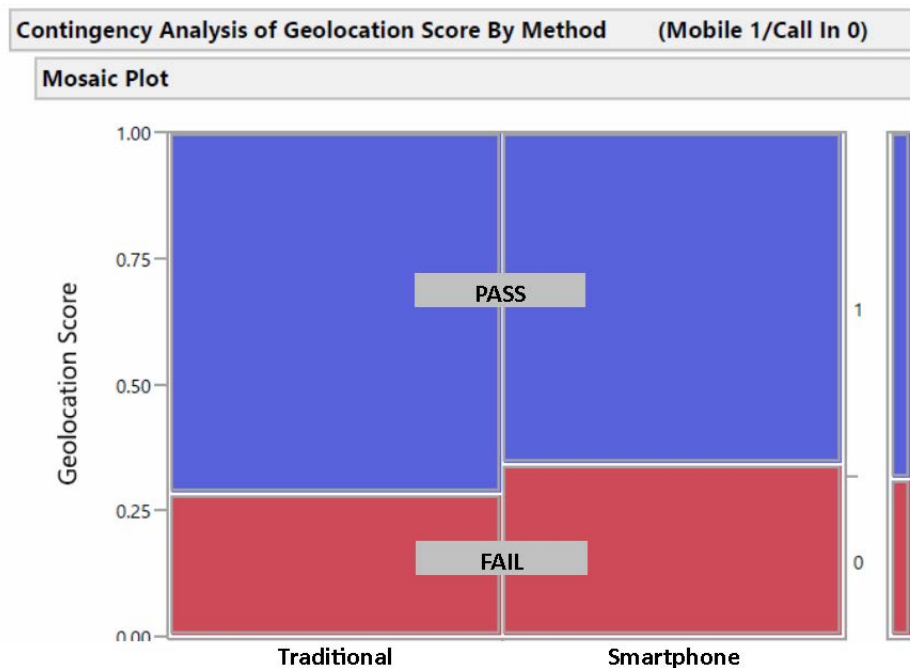
Non-parametric methods confirm the ANOVA test results. These results strongly indicate that all levels are communicating the same level of description ratio. With this

confirmation of the smartphone-based submission capability, when compared to traditional methods capability; it can be verified that smartphones do indeed submit the description ratio at the same level of an expert, regardless of facility diagnostic experience.

Analysis of Geolocation and Duplication Detection

In addition to the three analyses, analysis was done to examine how the methods affected geolocation and duplication detection. Although theoretically, all subjects should be equal with their ability to do both, earlier research in Chapter 2 did reveal that there are many factors that determine an individual's ability to figure out their geolocation. Where duplication is more related to a combination of how an individual description of the objects specificity level, and geolocation description. Starting this analysis was the evaluation of geolocation results for both methods. Geolocation was scored with either a 1 for an individual correctly labeling the location within the distance that the craftsmen said they needed and 0 for incorrectly defining their location. These results are shown in Figure 24.

Figure 24: Geolocation By Method Analysis

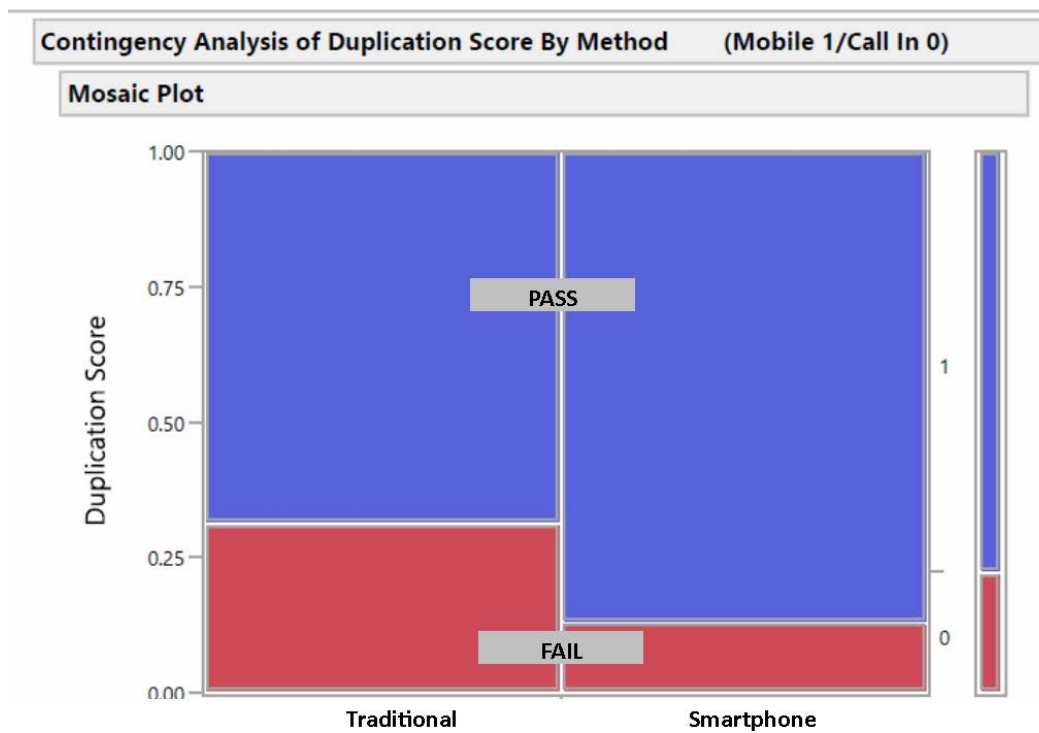


Geolocation Location Rate		
	Fail	Pass
Traditional Submission	22.88%	71.45%
Smartphone Submission	34.54%	65.46%

From the contingency table, a fisher's Exact test was calculated comparing the pass or failure frequencies of traditional submission, and smartphone-based submission methods. The hypothesis was that smartphone submission would produce a higher frequency of passes. From test results, it reveals that the probability of mobile submission having a higher pass rate than traditional submission is $p > 0.05$. With p greater than 0.05, this indicates that there is little chance of mobile submission having a higher pass rate than traditional submission. To confirm these results a Chi-square test was calculated. Significant deviation between the two submission methods was found ($\chi^2(1) = 4.79, p < 0.05$). This solution confirms that the methods do have a significant difference. This significant difference can be observed when looking at the descriptive statistical results listed with Figure 24. It can be seen that geolocation was very poor when compared to traditional submission users, with traditional users having their geolocation correct 71% of the time, compared to smartphone users being correct only 65% of the time. There was an assumption that the background geolocation portion of the application would assist in determining the individual's location. When an individual incorrectly determined their location, the geolocation was checked to see if it had correctly captured their location, and could be used in conjunction with the individual description to pinpoint the scenarios location. Most of the time the geolocation for interior work orders it would determine the correct building, but beyond that was useless in assisting in the geolocation of the work order. Exterior work orders had a similar problem of finding the correct location. Many times, the location would be close, but to general, in other instances, the submitted location was upwards of a quarter mile away.

Duplication detection was then analyzed to look at how the different methods enabled detection of duplicates. Duplication detection was either labeled a 1 for the combination of geolocation, and object description being strong enough that a controller or craftsman would be able to determine if a duplicate work order was being submitted. Or 0 if the descriptions were so vague, that a duplicate could be submitted, and no one would recognize it. These results are shown in Figure 25.

Figure 25: Duplication Detection By Method Analysis



Duplication Detection Rate		
	Not Detected	Detected
Traditional Submission	31.52%	68.48%
Smartphone Submission	13.30%	86.70%

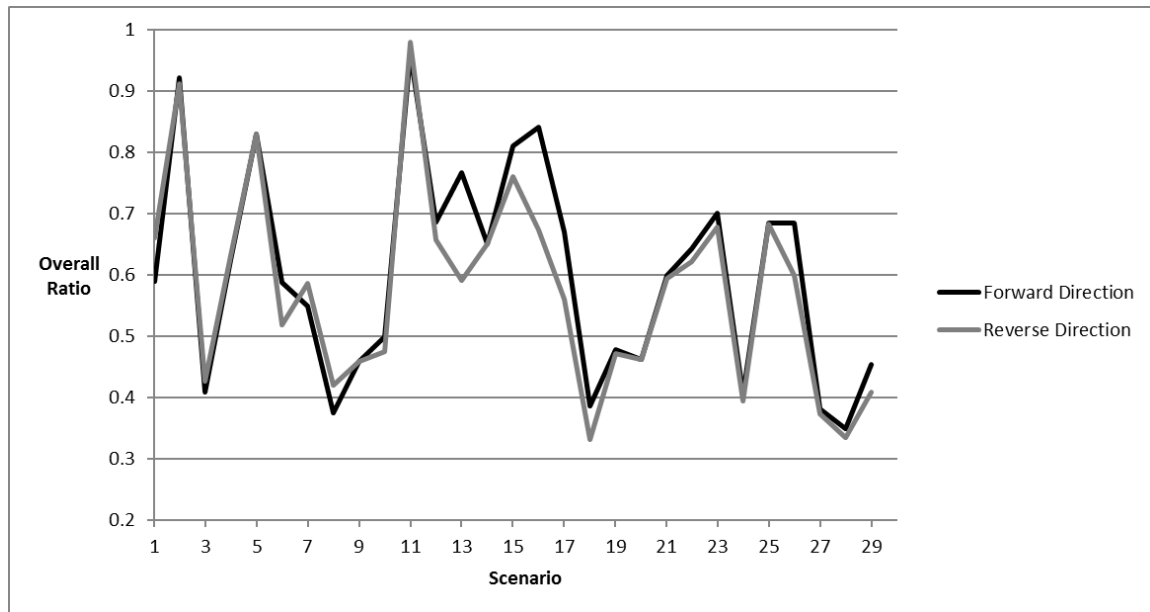
From the contingency table, a fisher's Exact test was calculated comparing the pass or failure frequencies of traditional submission, and smartphone-based submission methods. The hypothesis was that smartphone submission would produce a higher frequency of passes. From test results, it reveals that the probability of mobile submission having a higher pass rate than traditional submission is $p < 0.05$. With p less than 0.05, this indicates that there is a greater chance of mobile submission having a higher pass rate than traditional submission. To confirm these results a Chi-square test was calculated. Significant deviation between the two submission methods was found ($\chi^2(1) = 55.02, p < 0.05$). This solution confirms that the methods do have a significant difference. Further analysis of Figure 25 confirms that Smartphone-based submission resulted in a substantial increase in the ability to detect duplicates, with the traditional system only being able to detect duplicates 68% of the time, while the smartphone-based system is capable of detection 87% of the time. It is determined that this increase is mostly attributed to the highly rich visual media, utilized by the smartphone-based submission system.

Analysis of Potential Factors for Submission results

In addition to the four analyses, analysis was done to examine the effect of potential learning curve through direction, direction, education, and gender. These tests were conducted to make sure that the experiment wasn't inadvertently catered to a particular group.

Analysis of if there was a learning curve associated with the test was conducted first. To proceed with the test initially, the data was sub-set by direction through the course. After subsetting, the data was then analyzed by determining the overall usefulness ratio mean on a scenario by scenario basis for each direction independently. These means were then graphed together by scenario to see if an individual's direction through the course gave them any advantage. These results are summarized in Figure 26.

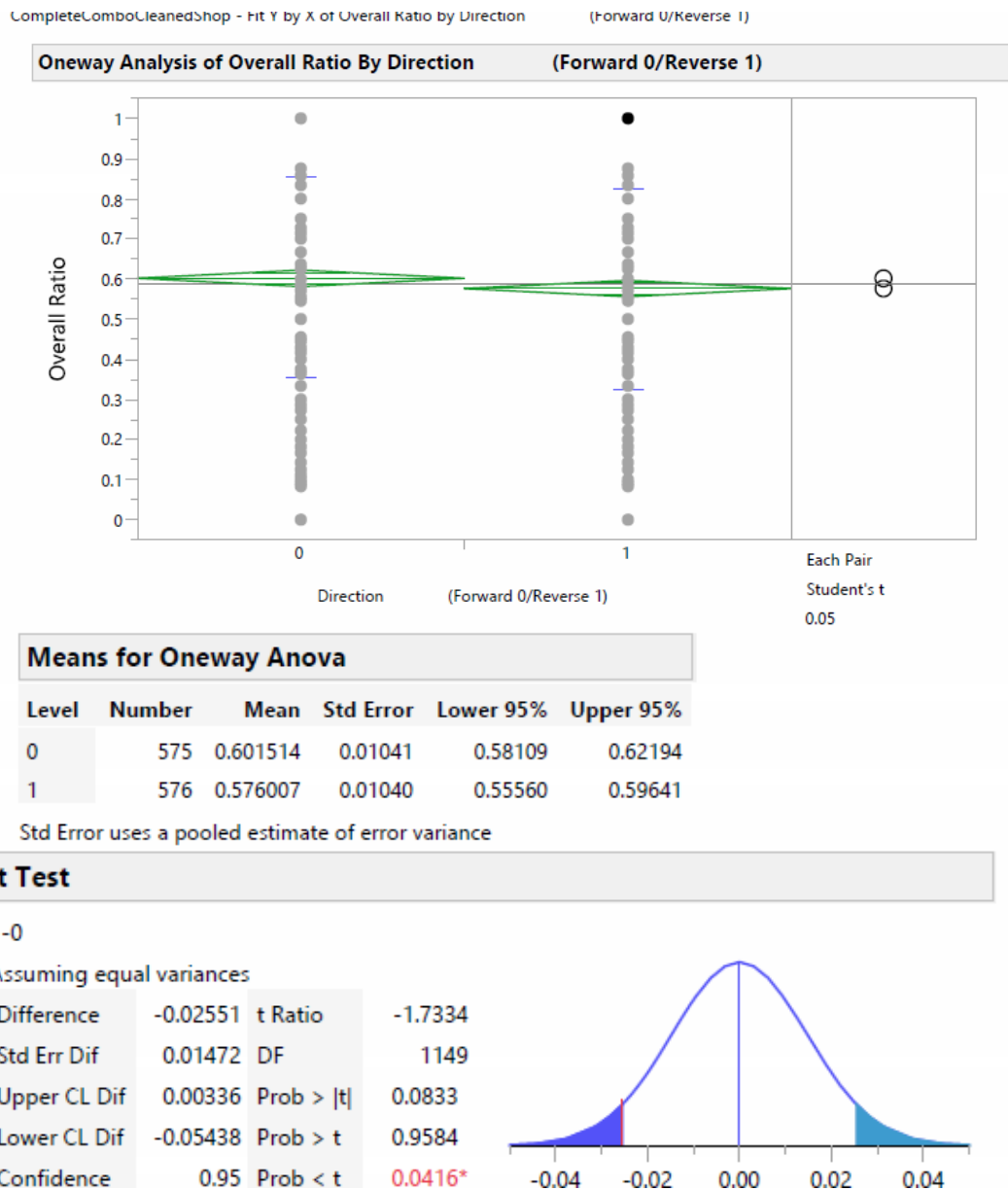
Figure 26: Learning Curve Analysis By Overall Usefulness Ratio



From looking at Figure 26, it can be observed that even though there are some areas that show marginal better performance, overall the graph shows that no matter the direction there wasn't a learning curve associated with the testing. If a learning curve was present, there would be what appear to be a U in the data set above, with the ratio increasing steadily as the scenarios increase for forward, and ratio decreasing as scenarios increase for reverse.

Showing that there is no learning curve with the data, the next area of interest was whether direction had an impact on overall usefulness ratio. Initially, the data was subset by direction, into forward and reverse. An independent t-test was conducted, with the assumption that all of the samples were independent. Results from the T-test are shown in Figure 27, with 0 being the forward direction, and 1 being the reverse direction.

Figure 27: Direction Analysis By Overall Usefulness Ratio



From the analysis seen in Figure 27, it can be seen that there is no significant difference between the two directions ($t(1149) = -1.73$, $P > 0.05$) failing to reject the null hypothesis; indicating that there is no difference in direction. The overall usefulness ratio mean for the forward direction was 0.61 ($sd = 0.25$), and the mean for reverse direction was 0.58 ($sd = 0.25$).

There is evidence though that the forward direction did have a better mean of overall usefulness ratio, but it was not significantly better.

To confirm these findings the test must pass normality and variance. Sample fails for normality (Shapiro-Wilk W Test) but does pass variance(Levene). Therefore the non-parametric Wilcoxon/Kruskal-Wallis Rank Sum test was utilized to verify results. Results are shown in Figure 28.

Figure 28: Non-Parametric Analysis of Overall Usefulness Ratio and Direction

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)					
Level	Count	Score Sum	Expected Score	Score Mean	(Mean-Mean0)/Std0
0	575	340402	331200	592.003	1.634
1	576	322575	331776	560.025	-1.634

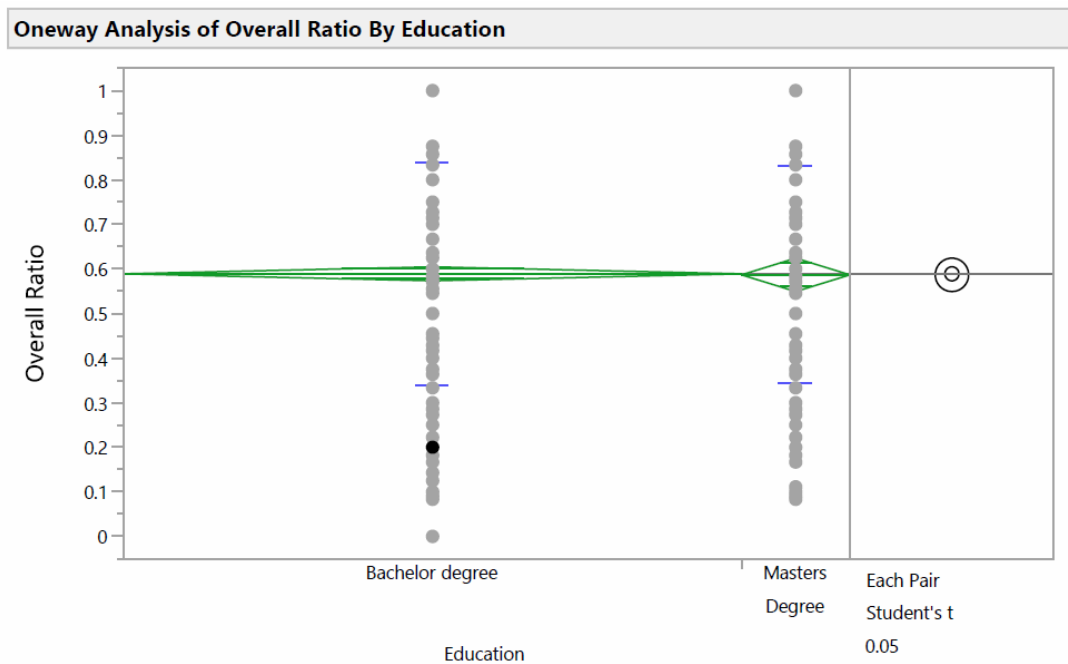
Oneway Analysis of Overall Ratio By Direction (Forward 0/Reverse 1)									
Nonparametric Comparisons For Each Pair Using Wilcoxon Method									
Level	- Level	Score Mean		Z	p-Value	Hodges-			
		Difference	Std Err Dif			Lehmann	Lower CL	Upper CL	
1	0	-31.9757	19.56405	-1.63441	0.1022	-0.012987	-0.053030	0	

Non-Parametric analysis confirms that there was no significant difference between the two directions ($Z = -1.63$, $p > 0.05$). This analysis also shows that forward direction had a slight advantage over the reverse. The reasoning for this difference is that there were 11 smartphone submissions when going the forward direction, and only 9 for reverse. Even with the difference of only two subjects using the smartphone submission; since the smartphone has a much better overall usefulness ratio this difference of two skews the forward direction to a slightly better overall usefulness mean. This difference in submission quantities was first explored at the beginning of Chapter 4 in the Information and Demographics Collected section and was displayed with Figure 11: Test Subject Direction and Method Distribution. Overall, however, the

test confirms that there was not a significant advantage of test subjects that went in the forward or reverse direction.

Education was then tested to see if education played a role in an individual's ability to submit higher level overall usefulness ratios. Analysis was done by looking at the overall usefulness ratio when compared to the two education levels present for the test (master's degree, and bachelor's degree). A t-test was conducted, with the consideration that all samples were independent, these results are summarized in Figure 29.

Figure 29: Education and Overall Usefulness Ratio

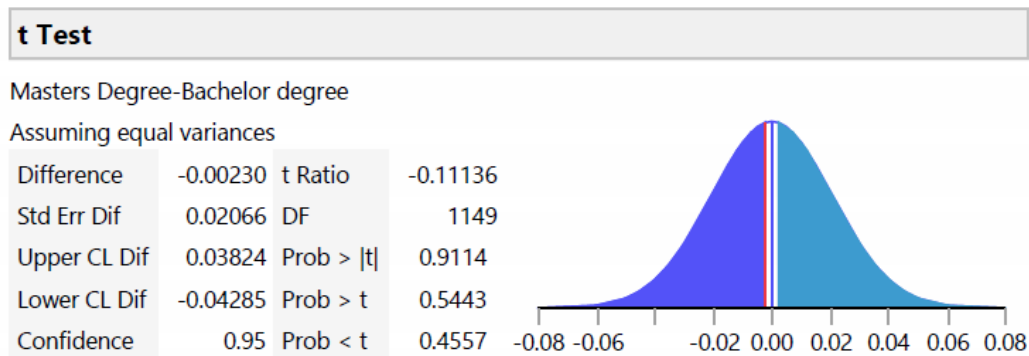


Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
Bachelor degree	979	0.589093	0.00799	0.57342	0.60477
Masters Degree	172	0.586792	0.01906	0.54940	0.62418

Std Error uses a pooled estimate of error variance

Continuation of Figure 29



From the analysis seen in Figure 29, it can be seen that there is no significant difference between the two education levels ($t(1149) = -0.11$, $P > 0.05$) failing to reject the null hypothesis; indicating that any individual regardless of education levels submits the same information. The overall usefulness ratio mean for master degree was 0.59 ($sd = 0.24$), and the mean for bachelor degree was 0.59 ($sd = 0.25$).

To confirm these findings the test must pass normality and variance. Sample fails for normality (Shapiro-Wilk W Test), but does pass variance(Levene). Therefore the non-parametric Wilcoxon/Kruskal-Wallis Rank Sum test was utilized to verify results. Results are shown in Figure 30.

Figure 30: Non-Parametric Analysis of Overall Usefulness Ratio and Education

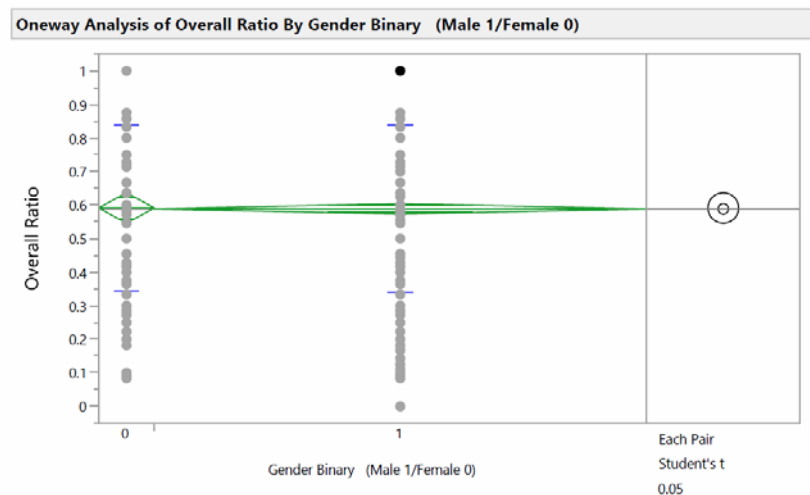
Wilcoxon / Kruskal-Wallis Tests (Rank Sums)					
Level	Count	Score Sum	Expected Score	Score Mean	(Mean-Mean0)/Std0
Bachelor degree	979	564552	563904	576.662	0.161
Masters Degree	172	98424.0	99072.0	572.233	-0.161

Nonparametric Comparisons For Each Pair Using Wilcoxon Method								
q*		Alpha						
1.95996		0.05						
Level	- Level	Score Mean		Hodges-				
		Difference	Std Err Dif	Z	p-Value	Lehmann	Lower CL	Upper CL
Masters Degree	Bachelor degree	-4.42592	27.43775	-0.161308	0.8719	0	-0.041667	0.0333333

Figure 30 verifies through non-parametric methods that there was no significant difference between education levels ($Z = -4.43$, $p > 0.05$). Indicating that there is a failure to reject the null hypothesis and all education levels submit the same level of information. This strongly indicates that education level had no effect on an individual's overall usefulness ratio score.

Last of the analysis to be done, is to see if gender played a role in a test subject's ability to submit higher overall usefulness ratios. A t-test was utilized to test between the two genders, or male and female, with all samples considered to be independent. Results of this test are in Figure 31.

Figure 31: Gender and Overall Usefulness Ratio

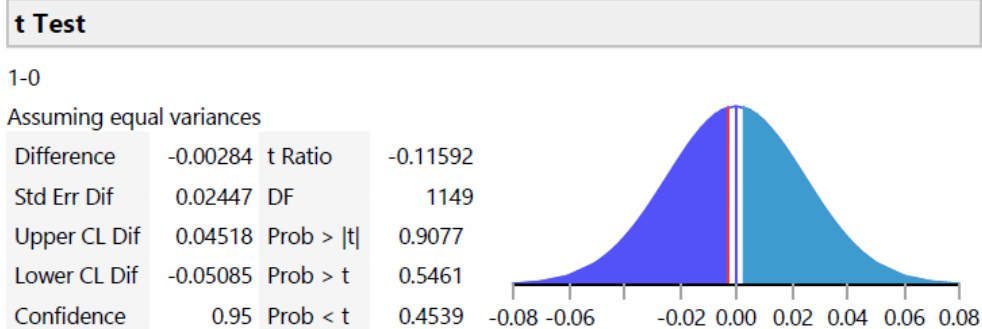


Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
0	116	0.591300	0.02321	0.54577	0.63683
1	1035	0.588463	0.00777	0.57322	0.60371

Std Error uses a pooled estimate of error variance

Continuation of Figure 31



From the analysis seen in Figure 31, it can be seen that there is no significant difference between gender ($t(1149) = -0.11$, $P > 0.05$) failing to reject the null hypothesis; indicating that gender plays no role in determining overall usefulness ratio. The overall usefulness ratio mean for females was 0.59 (sd = 0.25), and the mean for males was 0.59 (sd = 0.25).

To confirm these findings the test must pass normality and variance. Sample fails for normality (Shapiro-Wilk W Test) but does pass variance(Levene). Therefore the non-parametric Wilcoxon/Kruskal-Wallis Rank Sum test was utilized to verify results. Results are shown in Figure 32.

Figure 32: Non-Parametric Analysis of Overall Usefulness Ratio and Gender

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)					
Level	Count	Score Sum	Expected Score	Score Mean	(Mean-Mean0)/Std0
0	116	67332.0	66816.0	580.448	0.152
1	1035	595644	596160	575.501	-0.152

Oneway Analysis of Overall Ratio By Gender Binary (Male 1/Female 0)								
Nonparametric Comparisons For Each Pair Using Wilcoxon Method								
Level	- Level	Score Mean		Hodges-				
		Difference	Std Err Dif	Z	p-Value	Lehmann	Lower CL	Upper CL
1	0	-4.94203	32.49413	-0.152090	0.8791	0	-0.050000	0.0454545

Non-Parametric analysis confirms that there was no significant difference between genders ($Z = -0.15$, $p > 0.05$). This indicates that gender has no effect on the overall usefulness ratio except that females do have a slightly higher overall ratio, but not by much.

Conclusion

In conclusion to Chapter 4, it can be seen from the results; there is substantial evidence that smartphone-based mobile work order submission applications allow for individuals to submit work orders in a far superior way to current traditional submission methods. First the confirmation that smartphones do perform better in delivering a higher overall information usefulness ratio. Second is smartphones mitigate the CE organizational language barrier. Third was that smartphones enable all individuals regardless of facility diagnostic experience to submit work orders at the same level of an expert utilizing the same method. Finally, geolocation and duplication detection were examined to see if smartphone technology allowed for an improvement over traditional submission methods. For geolocation, smartphone technology produced an accurate location less dependable than traditional methods, which was not expected. With duplication, detection smartphones did a much better job at generating a submission resistant to accidental duplication. These results are summarized in the following Figure 33.

Figure 33: Smartphone-Based Work Order Submission Test Results

Smartphone Test	Result
Submit Information With A Higher Overall Usefulness Ratio Than Traditional Systems	Validated
Mitigate Organizational Language Barrier	Validated
Mitigate Facility Diagnostic Experience Advantage	Validated
Duplication Detection Improvement	Validated
Geolocation Accuracy Improvement	Failed

Additionally, the factors of learning curve, direction, education, and gender were explored to see if the test was accidentally biased by any of these factors. Learning curve, direction, education, and gender were thoroughly analyzed and were found to have no significant effect on overall usefulness ratios. Since none of these factors had an impact on overall usefulness ratio; it can be confirmed that the results found relating to an increase in overall usefulness ratio, mitigating the CE organizational language barrier, and ability to enable any individual regardless of facility diagnostic skill level to submit information at the level of an expert, can be completely attributed to the group of test subjects utilizing smartphone-based work order submission technology.

V. Conclusions and Recommendations

Chapter Overview

Conclusion and Recommendations section reviews the findings of the study, which confirmed that smartphone-based work order submission technology does deliver more useful information, breaks down organizational barriers, and allows any individual to submit a work order at the level of an expert. Additionally, the significance of the research is summarized along with recommendations for action. Finally, the conclusion closes out with recommendations for future research.

Conclusions of Research

Through this study, it was determined that the use of smartphone-based mobile work order submission technology does enable customers to accomplish what traditional submission systems are not currently capable of, especially when in the hands of average customers. Through testing methods developed at AFIT, this study was able to determine the following results. First smartphones do perform better in delivering a higher overall information usefulness ratio. Second, smartphones mitigate the CE organizational language barrier. Third, smartphones enable all individuals regardless of facility diagnostic experience to submit work orders at the same level of an expert utilizing the same method. Finally, geolocation and duplication detection were examined to see if smartphone technology allowed for an improvement over traditional submission methods. For geolocation, smartphone technology produced an accurate location less dependable than traditional methods, which was not expected. With duplication, detection smartphones did a much better job at generating a submission resistant to accidental duplication.

Additionally, the factors of learning curve, direction, education, and gender were explored to see if the test was accidentally biased by any of these factors. Since none of the gathered demographic factors had an impact on overall usefulness ratio; it can be confirmed then

the results found can be attributed to the group of test subjects utilizing smartphone-based work order submission technology.

Significance of Research

This study determined smartphone-based work order submission systems not only allow provides tremendous amounts of information, but the information that is provided is useful information as determined by the end user, the craftsmen. Since craftsmen received more useful information tailored to their needs, they can make highly informed decisions under conditions of uncertainty. This reduction in uncertainty allows not only informed decisions when potential emergencies arise, it also enables craftsmen to proceed to the job site just once, eliminating a verification run. From the work orders surveyed in this study just from Dover AFB if there was the elimination of even 30% of 20-minute verification runs for work orders that would equate to approximately 6373 work orders annually. For a standard work crew of two craftsmen billing at \$54 an hour, that equates to \$69K a year for just one base, not including costs associated with vehicles.

From an emergency response perspective, smartphone-based submission systems allow for individuals to submit work orders 24 hours a day, anywhere in the US, with no prior knowledge of the bases CE submission system. Submissions which then can be evaluated as to the level of emergency (or not one at all) by any controller or craftsman that is on call and has the capability of receiving the work orders via computer or smartphone. Enabling craftsmen to diagnose system problems at a long distance may provide significant savings on false emergency calls resulting from controllers not fully understanding the problem as reported with the traditional system. Remote diagnostics through smartphone-based submission also allows the craftsmen to directly contact the customer for immediate remedial actions to control the damages. Considering that an overflowing toilet can release almost a gallon a minute, which may not sound

significant, but factor in a potential 30-minute response time, 30 gallons of water can do a tremendous amount of damage to a structure, especially a multi-story one, prompting removal of personnel from lower floors, and impacts to every facility system to include electrical, communications, fire detection, notification, and climate control systems. With remote diagnostics, however, if a craftsman can get the customer to immediately perform a valve closure within the first 5 minutes, thousands of dollars in damage could be avoided. With an emergency response to be conducted in the same amount of time; potentially with the repair part in hand because of the system's ability to provide the craftsman in-depth knowledge of the system prior to their response. In addition to delivering useful information, the delivery of this information does not need to be accomplished by an expert. This research shows that the smartphone-based submission system allows any individual to provide the same level of useful information regardless of their prior facility diagnostic experience.

Elimination of facility diagnostic experience isn't the only area the smartphone application mitigates. Having to know the CE "lingo" is mitigated as well. Smartphone-based systems overcome the CE organizational language barrier which can hinder other groups to communicate with CE at the language specialization level required for effectively communicating to CE of what the actual issue is.

Mission continuation is also a unique aspect of the smartphone-based submission system. With traditional systems, the ability to relay base damage to a commander from the unit control center (UCC), emergency operations center (EOC), or command post (CP) was limited to audio transmissions and spreadsheets. During alarm black initial release, Civil Engineering (CE) post-attack response (PAR) teams attempting to report damage were forced to rely on concise radio/phone messages. Controllers then updated a spreadsheet and placed a pin on the map. These reports must be analyzed to determine the criticality of the issue which may or may not

reflect actual emergency conditions. PAR teams could take upwards of an hour to gather what amounts to extremely limited information about the extent of the damages to the base and resultant mission impacts. In addition to PAR teams, in the squadron, UCC reps gather information from their squadron regarding damages to their facilities and associated mission impacts. CE EOC representatives attempt to find these damages on the UCC spreadsheet, then must notify the CE UCC of the need to add an additional work order. If not descriptive enough infrastructure damage could be reported multiple times via various UCC representatives resulting in duplicated work orders. The EOC director determines which portion of the mission to bring back up first based on the CE UCC spreadsheet, if duplicated, or incorrect information exists on the spreadsheet this could hinder the director from making a decision that would have the most impact on getting the mission getting back up and running.

Smartphone-based submission is a potential solution to this problem, with all entities utilizing smartphones instead of the entire base trying to utilize one CE radio net, one UCC phone/controller, and one EOC CE phone/rep. Instead, the entire base utilizes GPS located information rich work orders. Not only is the information actually informative, but thousands of work orders can be submitted all at the same time by anyone on the base that has a visual with damage. The concept of that every Airmen is a sensor empowers any Airmen to become a sensor for their immediate area, allowing an extensive base site picture nearly instantly. These multitude of work orders are highly resistant to duplication, and when automatically displayed on a map, any commander, UCC, EOC, or CP can instantly see concentrations of damage, as well as pictures, and descriptions of the damage. This method enables an opening of the phone and radio nets for true emergencies that need instant rectification, or coordination of utility repair. In addition, the commander can have an instant visual of what is impacting the mission versus a short sentence and pin on a map.

Recommendations for Action

With no doubt this research has determined that smartphone-based work order submission allows any individual to submit work orders at the level of an expert, delivering useful information to CE craftsmen to make informed decisions and thus saving the Air Force time and money. The system does this by addressing cost reduction for the most expensive part of a facilities life cycle, the maintenance portion of the facility life cycle. In addition to saving time and money, the system allows enhanced capabilities for mission continuation, from day to day operations all the way to disaster recovery.

This study only scratched the surface of smartphone-based work order submission, determining that the system is incredibly more than capable of delivering useful information, while also breaking down experience and language barriers. It is recommended to do further research into the areas of advanced collection methods and integration of a commercial system into Tririga.

Recommendations for Future Research

Even though the study found the smartphone application provided significantly more useful information compared to the traditional work order system, the smartphone-based system only provided 74% of useful information CE craftsmen felt they needed. After interviews with the end users of the information, they identified several key areas for future research that would push this ratio up.

After discussing what they would consider being useful information, there was a consistent trend that the pictures are great, but lack data that could be significant in repairing problems that are hidden from view, such as electrical, alarms, and climate control systems. This indicates the smartphone systems would need more advanced methods of collecting related information on infrastructure issues. The study would need to explore first what information

would be needed (i.e. blueprints, schematics...etc.) and then how to implement the advanced collection method. Most likely this implementation of advanced collection would involve tagging and occur when the facility was constructed or retrofitted. Ideas for the tagging were for either a barcode or some passive radio transmission that a smartphone could receive. This tag printed or implanted on the equipment would be captured when the smartphone was submitting the work order. The smartphone would then use the tag to look up the infrastructure item in a back-end system which would communicate with an equipment database within Tririga, and determine what exactly the equipment is. Exact equipment data would then be included with the work order transmission to the craftsmen for completion. Just by doing this one step the usefulness ratio would be increased.

In addition to passive data gathering, the ability of the system to determine measurements of objects in the picture would also be a tremendous advantage to craftsmen that are in trades more related to structural facility items. Research into how a smartphone could gather this information without having a user physically put a ruler in the photograph would significantly increase the capability of the system.

For some facility systems, a history of the item or system is essential for repair. Having an automated infrastructure item history look up is directly related to the smartphone system's ability to communicate with Tririga and equipment tagging. If successful, a craftsman would have the ability to not only see the equipment present at the problem location, but also a history of the particular item. Savings from this type of data collection are generated from the ability to target reoccurring problem systems for replacement or extensive repair.

Integration with Tririga and a subsequent real-world experiment is one of the last big areas of research that need to be addressed to evaluate the functionality of the smartphone system. First, the system must be fully integrated with Tririga so that there isn't a need for extensive data

transfer. Second, a real-world study is critical because no matter how much theorizing or simulation work is done, the system in the hands of users and craftsmen will determine the true potential cost savings and unknown failures within the system from emergent system behavior.

Summary

In summary, the conclusion reviewed the findings of the study, which confirmed that smartphone-based work order submission technology does deliver more useful information, breaks down organizational barriers, and allows any individual to submit a work order at the level of an expert. Additionally, the significance of the research was summarized along with recommendations for action. Finally, the conclusion was closed out with recommendations for future research to further explore the capabilities of smartphone-based mobile work order submission systems.

Appendix

Appendix A: Grading Criteria

Scenario	Geolocation	Requirements	Duplication	Description	Requirements	Key Words									
1	Building and Room# 640-112) Outside Room Sign	Description must state/show sign is immediately outside the room on a wall.		Must describe that there is a sign on a wall, and its size. Assuming unless subject mentions outside of door on wall that there could be miss communication about whether a on the door name/placard, or on the wall type placard.	Sign	On Wall	Size								
2	Building and Room# 640 outside of men's room 102, or across from 103.	Description that clearly states/or show the sink is in the breakroom area and not in a bathroom.		Must include that it is a small sink, and overflowing.	Small Sink	Overflowing									
3	Building and Room# 640 (Across from Rm 304, between 302 and 303) Right bulletin board, light from right 4, from left 2.	Must clearly describe/show the board location, and light location.		Should describe, it a recessed can light fixture, voltage, wattage, bulb base, bulb shape, bulb type, type of fixture recessed can light, and size. As well as if there is only one out or many. Placed in the ceiling/overhang.	Light Out	Recessed Can Fixture Type	Size 4"	One/Many out	Voltage	Wattage	Bulb Shape	Bulb Base	Bulb Type		
4	Building and Room# 640-outside of room 307	Must describe/show that it is outside of room 307 and in the hallway.		Description that they are ceiling tiles, the number of tiles damaged, size of tiles, type of tile, style of track, and what's behind the tiles. Description/show what's leaking	Ceiling Tile Damaged	Number of Tiles Damaged	Style/Type of Tiles	Style of Track	Size of Tile	Description of what was leaking					
5	Building and Room# 640 outside of either 316, 318.	Must describe that it is a speaker/intercom/sound emitting device on the ceiling in the hallway.		That it is a speaker or sound producer, the approximately size/type, and how its falling out of ceiling e.x. how many screws remaining.	Speaker/Intercom	How it is falling out of the ceiling.	Size/Type								
6	Building and Room # 640-329	Must clearly indicate/show that the sink is in the break room 329		Should include that sink/drain is leaking, is a trap connected to the sink, drain leaking, trap type(P-Trap), fittings connecting to sink, trap material, and trap size.	Sink/Drain Leaking	Trap Connected to Sink	Trap Type	Fittings Connected to Sink	Trap Material	Trap Size					
7	Building and Room # 642-212 on the right side inner door	Must clearly describe/show that it is an inner door on the right side of Kenney hall, next to the men's room.		Description that it is a door, the door type, and that it is sticking. As well as a description/show of the inside of the door/frame when open, and when closed.	Is a Door	Door Sticks	Door Type	Inside of Door Frame	Inside Door Frame When Closed						
8	Building, room, and Device # 642- outside the left side of Kenney hall 212/by CCR Sign on the 2nd floor outside of room 212/stairwell on the 2nd floor by the CCR sign near room 212/ by the CCR sign across from Kenney hall rm 212, next to a hallway.	Must clearly describe/show that the location is a pull station on the wall outside of Kenney hall/by CCR Sign/by stairwell/in hallway.		That it is a fire pull station, In-op kind of fire panel(Addressable/non-addressable), panel readout, address of device, brand, model, and part number.	Pull Station	In-op	Kind of Panel(address/non-address)	Panel Readout	Address of Device	Brand	Model	Part Number			
9	Building and Room# 641-Outside of room 209/211/206 in the hallway	Must be able to distinguish/show the difference between the broken fixture and the others.		Should describe, it a troffer light fixture, voltage, wattage, bulb base, bulb shape, bulb type, number of bulbs, and size. As well as if there is only one out or many.	Light Out	Troffer Fixture Type	Size 2X4	One/Many out	Voltage	Wattage	Number of Bulbs	Bulb Shape	Bulb Base	Bulb Type	
10	Building and associated location, 641 across from RM 210/215/Stairwell 3 Level 2	Must be able to distinguish/show that the thermostats location is unique.		That it's a thermostat/control, VAV# 2-41, current temperature, set point temperature, it has a broken cover, other areas in the building that are experiencing temperature swings, address to the control/thermostat, brand, model, serial number.	Thermostat/Control	Broken Cover	Broken/inop	VAV # Controlled/ address	Current Temp	Set Point Temp	One area/Multi Area	Brand	Model	Serial Number	
11	Building and location, building 641-215	Distinguish/show the location that is producing the sound		The room location, that is making unusual sounds, it's a mechanical room, and to describe the sounds.	Mech Room	Unusual Loud Noises	Describe Noises								
12	Building and room#, 643-near room 302 on the right side, across from room 301 on the right side.	Distinguish/show that the water fountain is on the right side when looking from the front. If not that then additionally it has the code ZHTV 503461		Water fountain, make, model number, with a slow flow/broken in some way, and knob functions/description of the water flow.	Water Fountain	Slow Flow/inop	Knob Works/Water Flow Description	Make	Model Number						
13	Building and room# 643-301, and wall side N,S,E,W.	Distinguish/show the wall location that the outlet is on.		Describe that it is an outlet w/cover that has a 1/4+ slot/hole on the side of the cover.	Outlet	Cover Plate Not Covering Hole in Wall	Hole Size	Hazards/Exposed Wires							
14	Building and room# very specific location required, 643- across the hall from rm 306, in the large CE atrium area, near the elevators.	Distinguish/show the location of the panel, and its most distinguishing mark RTU-1		Describe/show its an access panel with code RTU-1, describe what's leaking inside, and leaking speed.	Access Panel	Leaking	Leak Description/Speed	Panel Code RTU-1	What Was Leaking Inside						
15	Building and room# 643- in 2nd floor CE atrium, across from elevator. Door with handle is one that is causing the problem.	Distinguish/show the location of the door as the door with the handle. Or from the elevator on the right, or from the hallway on the left.		Describe/show that the door is sticking in the ajar position and will not self close, and that the door has a strike plate that is jamming the door.	Door	Will Not Self Close/Sticks Open	Strike Plate Jamming Door								
16	Building and room # 643-first floor atrium opposite of elevator/south wall	Distinguish/show the wall location that the fin tube radiator cover is located on		That there is a fin tube radiator, with a cover that had been moved/broken and was no longer aligned with the other covers, there is no problem with the actual fin tube and just a cover.	Fin Tube Radiator	Cover Moved/Broken	Realign Cover	Radiator Tube not Broken Just							
17	Building and room# 643-first floor atrium across from elevator, near the west entrance.	Distinguish/show the location of the EM switch		Describe which light is it, that the system is associated with emergency/HVAC operations, and what units were shutdown.	EM Light Illuminated	HVAC/Emergency	Units Shutdown								
18	Building, side of the building, and the approximate distance from the structure, location along the building. On southwest side of building 643, by the atrium, 20ft. south of West entrance to building 643, 10ft. south of atrium wall.	Describe/show the side of the building and where the crack is located along the building.		Describe/show length/width of crack, main walkway or not, size of the slabs, number of slabs affected, depth of the slabs. Is there holes nearby, or obvious settling.	Broken/cracked Sidewalk	Length of Crack	Width of Crack	Size of Slabs	Number of Slabs Affected	Main Walkway	Depth of Slabs	Holes Nearby	Obvious Settling		
19	Building, side of the building, nearby entrances, order of lights. Building 643 on south side, 2 lights to the left from the entrance when looking from the outside of the facility.	Clearly Describe/show the light location and which one it is in the sequence.		Describe/show that the light fixture lens is broken, the material is glass, the diameter, and it is the Fresnel lens to an exterior recessed can light fixture.	Light Fixture Lens Broken	Material Glass	Diameter	Recessed Light Fixture	Fresnel Lens						

Scenario	Geolocation Requirements	Duplication	Description Requirements	Key Words									
20	Building, side of building, nearby entrances, distance from building, approximate landmark. 641, south side of building, 4th pillar west from east entrance/1 pillar east from west side of building, under overhang near picnic tables/across from AFIT flag.	Describe/show the sprinkler and show how it is different from the other sprinkler heads.	Describe/show that it is a fire suppression system that is experiencing problems and the escutcheon is falling out of the ceiling. Also need a size, finish type, style, and brand of the escutcheon.	Fire Suppression System	Escutcheon Falling out	Finish Type	Size	Style	Brand				
21	Building, side of the building, closest entrance the approximate distance from the structure, and location along the building. 641, south side of building, 4th pillar west from east entrance/1 pillar east from west side of building, 1 Ft south of/next to overhang near picnic tables/across from AFIT flag.	Describe/show the hole, and if there are any others like it	Describe/show hole depth and diameter, potential animal living in the hole, number of holes, if the ground looks unstable, or obvious settling is occurring in the area.	Hole	Potential Animal Hole	Number of Holes	Depth	Diameter	Unstable	Settling in Area			
22	Building, side of the building, closest entrance the approximate distance from the building, and location along the building. 641, south side of building, approximately 50ft directly south of east exit on the east exit walkway immediately as you are exiting the overhead area, laying on the sidewalk.	Describe/show the snakes physical features and location.	Describe/show that the snakes size of approximately 2ft, that its main colors are black red/brown, if it is in the open/bush/behind a wall, and whether it is moving.	Snake	Size of Snake	Main Colors	Moving or Still	In Open/Bush/Behind d Something					
23	Building and Room# AFIT Bldg. 642 - 1st Floor Ramp connecting Bldg. 641 and 642 near D'Azzo Research Library	Must describe/show that it is located above the ramp/hallway, connecting building 641 and 642 in the center section.	Description that they are ceiling tiles, the number of tiles damaged, size of tiles, type of tile, style of track.	Ceiling Tile Damaged	Number of Tiles Damaged	Style/Type of Tiles	Style of Track	Size of Tile					
24	Building and Room# Building 642- 1st floor hallway in between D'Azzo Research Library, and Einstein's bagel shop near the north end of the windows.	Must describe/show its unique feature of either ZHTV 503506/Fin Tube Radiator	Description that a fin tube radiator is not producing heat/heat like it should, location of boiler/exchanger, steam/hot water, valves, location of controls/thermostat, and if it's the only one not producing heat or if many in the facility are not producing heat.	Fin Tube Radiator	Not producing heat/heat like it should	Location of boiler/exchanger	Steam/ Hot Water	Valves	Location of Controls/Thermostat	One/Many			
25	Building and room# 642-123	Must describe/show the correct room	Description must include that it is a CAC/smart card reader with keypad that controls the door, and it is not letting the individual in, along with the color of the light at the top of the keypad.	Door Lock Doesn't Work/Not Letting Individual In	CAC/Smart Card Reader	Keypad	Color of Light At Top Of Reader						
26	Building and room# 642-loading dock by Einstein's bagel shop/RM126	Must describe/show that door stop is for the exterior entrance door to the loading dock area	Description must include that the door stop/bumper is damaged and needs to be replaced, size, type, mounting placement of bumper required as well.	Door Stop/Bumper Damaged	Needs Replacement	Mounting Placement	Size	Type					
27	Building and room# 642-loading dock by Einstein's bagel shop/RM126	Must describe that the thermostat/control is next to another thermostat/control, and the address associated with it T-UH-5-SP	Description must include that it is a thermostat/control that has a broken cover, current temperature, setpoint temperature, are there other areas in the building that are experiencing temperature swings, address to the control/thermostat T- UH-5-SP, brand, model, Serial Number.	Thermostat/Control	Broken Cover	Broken/Inop	VAV # Controlled/ Address	Current Temp	Set Point Temp	One area/Multi Area	Brand	Model	Serial Number
28	Building and room# 642-loading dock by Einstein's bagel shop/RM126	Must describe that the Fire Pull Station is next to another Fire Pull Station and the address associated with the Pull Station.	That it is a fire pull station, In-op, kind of fire panel(Addressable/non-addressable), panel readout, address of device, brand, model, and part number.	Pull Station	In-op	Kind of Panel(address/ non-address)	Panel Readout	Address of Device	Brand	Model	Part Number		
29	Building and room# 642-loading dock by Einstein's bagel shop/RM126	Must describe/show that it is the light fixture that is inside the loading dock area to the left of the roll up door, and not one of the other lights.	Florescent fixture that is flickering/dim, if it is the only one out or many, strip light with reflector, size of the fixture 4ftX 2 lamp , bulb typeT12, wattage32, and voltage120/277.	Light Flickering	Strip w/Reflector Fixture Type	Size 4Ft 2Lamp	One/Many out	Voltage	Wattage	Bulb Shape	Bulb Base	Bulb Type	

Appendix B: Work Order Scenario/Shop Counts

		Base WO Counts								
Shop	IWIMS Shop Code	Dover AFB	Dyess AFB	Hurlburt AFB	Langley AFB	Robbins AFB	Wright-Patt AFB	Sub-Total	% Of Work Orders	Scenarios
Structural	CA/PC	2340	1630	2132	2357	3141	5531	17131	22.9%	7
Electrical	IT	1411	1339	1505	1745	2875	4142	13017	17.4%	5
HVAC	WW	1772	1885	2359	2590	4189	5430	18225	24.4%	6
Water	EC	1643	2224	1539	2315	1352	4307	13380	17.9%	6
Entomology	LF	526	150	470	420	1103	788	3457	4.6%	2
Heavy	PX	476	227	313	347	584	890	2837	3.8%	2
Alarms	ET	178	282	991	553	1647	1965	5616	7.5%	1
Power Pro	OX	74	39	70	144	154	139	620	0.8%	0
Sweeper	EO	3	3	0	2	0	498	506	0.7%	0
Water Plant	HZ	0	0	0	0	21	0	21	0.0%	0
Base Sub Total		8423	7779	9379	10473	15066	23690	74810		
Base Count		8423	7779	9379	10473	15066	23690	74810		
Difference		0	0	0	0	0	0	0		

Appendix C: Scenario Guide/Standardized Verbal Hints

Location	Building	Room	Item	Hint	Structural	Electrical	HVAC	Water	Entomology	Heavy	Alarms	
1	640	112	Broken sign	Please report this item	x							
2	640	Break Room	Overflowing Sink	Please report this item as if it overflowing				x				
3	640	304	Light above the bulletin board is out	Please report this item as if it is not producing light		X						
4	640	307	Ceiling has water damage to tiles	Please report this item	x			x				
5	640	316	Speaker hanging out near 317	Please report this item		x						
6	640	329	Sink leaking	Please report this item keep in mind that this area is theoretically wet.(point under the sink)				x				
7	642	212	The 2nd floor inner door sticks	Please report this item keep in mind that the door sticks like this.(show door sticking)	x							
8	642	212	Outside of hall, inactive pull station	Please report this item							x	
9	641	211	Lights out	Please report this item		x						
10	641	215	Broken Thermostat next to bulletin board and schematic	Please report this item			x					
11	641	215	Loud sound coming from mech room	Please report this item as if there is a loud screeching sound coming from behind the door.			x					
12	643	302	Slow water fountain flow	Please report this item(turn the knob)				x				
13	643	301	Electrical outlet	Please report this item		x						
14	643	302	Access Panel by bath leaking	Please report this item as if water is trickling from the bottom				x				
15	643	2nd fl	2nd floor door sticks	Please report this item	x							
16	643	1st fl atrium	Heater broken	Please report this item			x					
17	643	1st fl atrium	EM Shutdown button lit	Please report this item as if the EM light is illuminated			x					
18	643	outside atrium	Cracked sidewalk	Please report this item						x		
19	643	outside atrium	Broken light lens	Please report this item		x						
20	641	Outside under patio	Broke sprinkler head escutcheon.	Please report this item				x				
21	641	Outside under patio	ground hog hole	Please report this item					x	x		
22	641	Outside under patio	Snake on the patio	Please report this item					x			
23	642	1st fl	Walkway missing ceiling tile	Please report this item	x							
24	642	1st floor hall	Wall heater not heating up	Please report this item as if it not producing heat like it should be.			x					
25	642	642-123	Door CAC Reader Inop	Please report this item as if this portion of the item isn't letting you in.	x							
26	642	loading dock	Door bumper broken	Please report this item	x							
27	642	loading dock	Loading dock bad thermo	Please report this item			x					
28	642	loading dock	Fire alarm inoperable	Please report this item							x	
29	642	loading dock	Bad Light Fixture	Please report this item		x						
					7	6	6	6	2	2	2	Count
					7	5	6	6	2	2	1	Required
					YES	YES	YES	YES	YES	YES	YES	GTG

Appendix D: Experiment Script/Post-Test Questionnaire/Contact Card

Experiment Script

0:00 Participant arrives at testing area on the first floor of building 640 by men's restroom.

"Welcome to testing of work order submission processes, today you will be testing smartphone/traditional work order submission. This test is voluntary and will last approximately 45-70 minutes. Upon completion refreshments will be offered. If you do not want to participate in this experiment then you may leave now or at any time during the experiment. If you wish to continue we will now be going over the informed consent form."

0:02 Have participant read and sign the Informed Consent Form/participant receives their number written at the top of the consent form.

0:05 Experiment Description/Training

"This experiment simulates submitting a work order to a civil engineering squadron. The study consists of mostly an interior work order submission items, but will also consist of a temporary exterior portion that should only last 5-10 minutes.

Throughout the AFIT complex we have identified a number of simulated and real world facility items that could be submitted to the facility manager or the civil engineering squadron to be replaced or repaired. We will identify these items by pointing to them. If you see a real world facility emergency that is not indicated by the researcher please notify the accompanying researcher. Under no circumstances are you to touch any facility infrastructure items during the experiment. If there are any questions during the course please ask the accompanying researcher. During the experiment if a real world emergency occurs please follow standard procedure regarding the particular emergency situation. If at any time you need to use the restroom please notify the accompanying researcher and utilize one of the restrooms along the route."

"Do you have any questions prior to training?"

0:07 Give training for smartphone and traditional

"All simulated work order submission items will be identified by the accompanying researcher. In some cases, the researcher will say a phrase about what the item is doing or not doing. During the experiment, you may ask the researcher if you are supposed to submit an item and point to it, they will respond with yes or point to the intended item. You may not ask what the item is or what is incorrect about it. For instance, we will show you a broken light, but not tell you what it is or how to describe it. All information that you submit must be from your own experience and interpretation from the phrase given by the researcher about the item. Are there any questions prior to instructions on the submission requirements?"

0:08 Traditional submission participants will be given this script portion

“You have been randomly selected to participate in traditional work order submission testing. You will follow the accompanying researcher through the work order submission course they will be present for questions relating to where you need to go and emergency procedure. To submit an item dial the following number 307-213-9677, the following message will play(play message) “Please answer the questions after the tone. What is your subject number? What is your location? And what is the infrastructure problem that you are trying to submit?” after the tone please answer the questions given by the message as if you were reporting an actual CE work order. Are there any questions? (Answer non revealing questions) Are you ready to begin the course? (if no remove participant from current test and try to reschedule)”

(0:08)

Smartphone submission participants will be given this script portion

“You have been randomly selected to participate in smartphone work order submission testing. You will follow the accompanying researcher through the work order submission course they will be present for questions relating to where you need to go and emergency procedure. (Show individual how to use the application) Open the application, select the submit icon(Open application, select submit) fill in your subject number, fill in your location,(Show individual how to do each step after saying it.) Select the camera and take a picture of the submission item. (Show how to take a picture of the WO item) If you feel like the picture doesn’t describe the problem fully please add an additional description here; this is optional, all of the other fields are required. (Show how to add additional description). After filling out the form select the WO Submit button to submit the form. (Show how to submit the WO). Please answer the questions on the smartphone as if you were reporting an actual CE work order. Are there any questions? (Answer non revealing questions) Are you ready to begin the course? (if no remove participant from current test and try to reschedule)

00:10 Send participants through course with researcher

Test Traditional WO Submission
Test Smartphone WO Submission

00:55 Ask participant to fill out post experiment questionnaire on computer

“Thank you for taking part in this test, would you please take a final post experiment questionnaire.” (Give individual the questionnaire on mobile computer”)

1:10 After filling out the questionnaire

“Please do not talk to anyone about the experiment, until you are notified from the researcher that the results have been posted. If you have questions or concerns about the experiment you can address them now with the researcher, E-Mail, or call with the number provided” (Give card with experiment contact information on it.)

Offer participant courtesy food and beverage

Contact Card

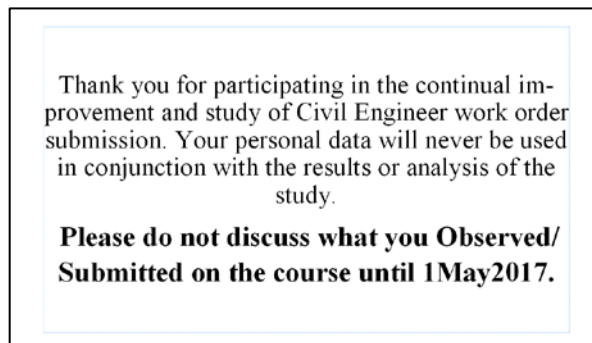


Figure 1: Front of card

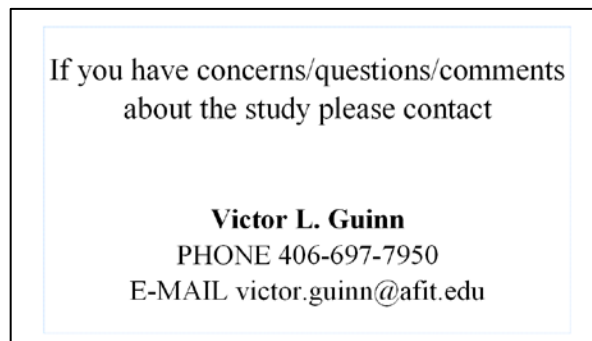
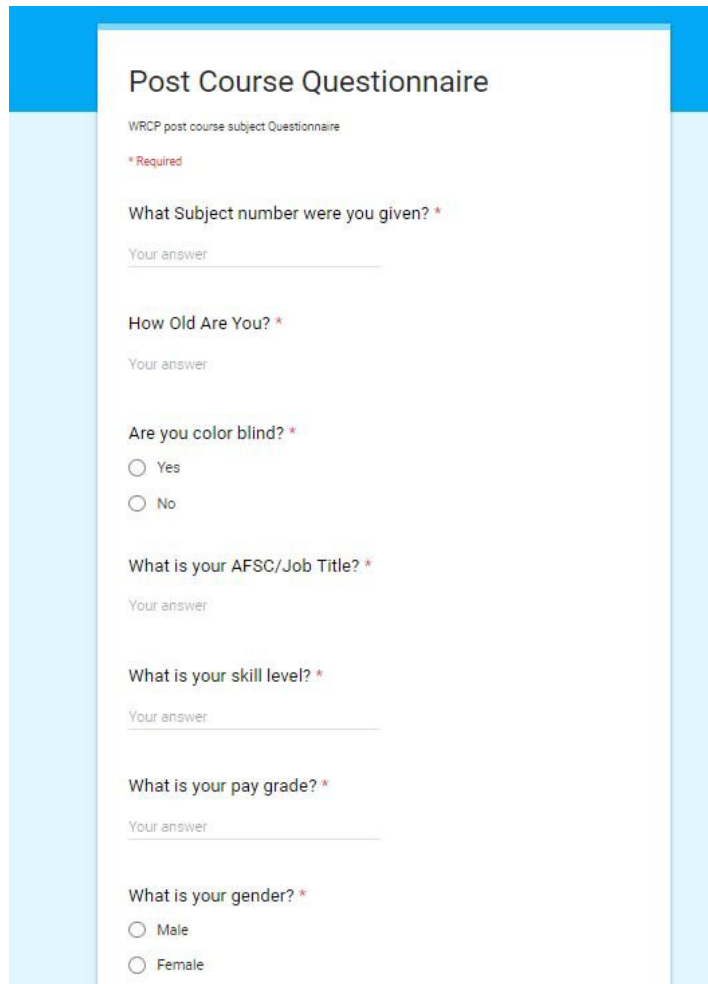


Figure 2: Back of Card

Post Course Questionnaire

To view interactive questionnaire go to <https://docs.google.com/forms/d/e/1FAIpQLSfmE0VF3qOE-6M85UVuN8WVJ3t5-K4aGb3je1ilcBh32eexvA/viewform?c=0&w=1>



The image shows a screenshot of a Google Form titled "Post Course Questionnaire". The form is set against a light blue background with a darker blue header. The title "Post Course Questionnaire" is at the top in a bold, black font. Below the title, the subtitle "WRCP post course subject Questionnaire" is displayed in a smaller font. A red asterisk indicates that the following question is required. The question is "What Subject number were you given? *". Below the question is a text input field with the placeholder text "Your answer". The next question is "How Old Are You? *", also marked as required, with a text input field and the placeholder "Your answer". The third question is "Are you color blind? *", marked as required, with two radio button options: "Yes" and "No". The fourth question is "What is your AFSC/Job Title? *", marked as required, with a text input field and the placeholder "Your answer". The fifth question is "What is your skill level? *", marked as required, with a text input field and the placeholder "Your answer". The sixth question is "What is your pay grade? *", marked as required, with a text input field and the placeholder "Your answer". The final question is "What is your gender? *", marked as required, with two radio button options: "Male" and "Female".

Post Course Questionnaire

WRCP post course subject Questionnaire

* Required

What Subject number were you given? *

Your answer

How Old Are You? *

Your answer

Are you color blind? *

☐ Yes

☐ No

What is your AFSC/Job Title? *

Your answer

What is your skill level? *

Your answer

What is your pay grade? *

Your answer

What is your gender? *

☐ Male

☐ Female

What is the highest degree or level of school you have completed or the highest degree you have received? *

- ☐ Less than a high school degree
- ☐ High school degree or equivalent (e.g., GED)
- ☐ Some college but no degree
- ☐ Associate degree
- ☐ Bachelor degree
- ☐ Masters Degree
- ☐ Doctorate degree

NEXT

Post Course Questionnaire

* Required

Post Course Questionnaire

WRCP post course subject Questionnaire

Prior to participating in this study, I already knew that the study was investigating operational security (OPSEC)? *

- ☐ Yes
- ☐ No
- ☐ Other: _____

I am an expert at diagnosing building system malfunctions. *

	1	2	3	4	5	
Strongly Disagree	☐	☐	☐	☐	☐	Strongly Agree

Prior to participating in this study, I already knew that the study was investigating operational security (OPSEC) and because of that knowledge I tried to avoid collecting critical information? *

	1	2	3	4	5	
Strongly Disagree	☐	☐	☐	☐	☐	Strongly Agree

I am familiar with the term Operational Security(OPSEC) and its meaning. *

	1	2	3	4	5	
Strongly Disagree	☐	☐	☐	☐	☐	Strongly Agree

I have participated in Operational Security (OPSEC) training at least one time in my life. *

	1	2	3	4	5	
Strongly Disagree	☐	☐	☐	☐	☐	Strongly Agree

I have participated in some type of Operational Security (OPSEC) training within the last 12 months. *

	1	2	3	4	5	
Strongly Disagree	☐	☐	☐	☐	☐	Strongly Agree

I understand the meaning of the term "Critical Information" and how it relates to Operational Security (OPSEC). *

	1	2	3	4	5	
Strongly Disagree	☐	☐	☐	☐	☐	Strongly Agree

I understand the meaning of the term "Indicators of Critical Information" and how it relates to Operational Security (OPSEC). *

	1	2	3	4	5	
Strongly Disagree	☐	☐	☐	☐	☐	Strongly Agree

During the experiment, I was (at least once) concerned that I might be collecting Critical Information. *

	1	2	3	4	5	
Strongly Disagree	☐	☐	☐	☐	☐	Strongly Agree

During the experiment, I was (at least once) concerned that I might be collecting Indicators of Critical Information. *

	1	2	3	4	5	
Strongly Disagree	☐	☐	☐	☐	☐	Strongly Agree

During the experiment, I was (at least once) concerned about operational security. *

	1	2	3	4	5	
Strongly Disagree	☐	☐	☐	☐	☐	Strongly Agree

During the experiment, I collected and/or communicated Critical Information. *

	1	2	3	4	5	
Strongly Disagree	☐	☐	☐	☐	☐	Strongly Agree

What work request collection method did you use during the experiment *

- ☐ Mobile application
- ☐ Call-in Method

BACK

NEXT

Never submit passwords through Google Forms.

Post Course Questionnaire

* Required

Mobile Application

The mobile application I used during the experiment was user friendly. *

	1	2	3	4	5	
Strongly Disagree	☐	☐	☐	☐	☐	Strongly Agree

Did you use the application to document location and problem? *

- ☐ Yes
- ☐ No
- ☐ I probably did but it was not intentional
- ☐ what does document location and problem mean?

BACK

SUBMIT

Never submit passwords through Google Forms.

Appendix E: Randomization Table

	Method	Direction
	1-Mobile	1-Top Down
Subject	0-Traditional	0- Bottom Up
1	1	0
2	0	0
3	0	1
4	1	1
5	0	0
6	1	0
7	0	1
8	1	1
9	0	1
10	1	0
11	0	0
12	1	1
13	0	0
14	1	1
15	0	1
16	1	1
17	0	0
18	0	1
19	1	0
20	1	0
21	1	1
22	1	0
23	0	0
24	0	1
25	0	0
26	0	0
27	1	1
28	1	1
29	0	0
30	1	1
31	0	1
32	1	0
33	1	1
34	0	1
35	0	0
36	1	0
37	0	1
38	1	0
39	1	1
40	0	0
41	1	1
42	0	1
43	0	0
44	1	0
45	1	1
46	0	0
47	0	1
48	1	0
49	1	1
50	1	1
51	0	0
52	0	0
53	0	1
54	1	0
55	1	0
56	0	1
57	1	1
58	0	1
59	1	0
60	0	0
Total	30	30

Appendix F: Institutional Review Board Approval

THIS PAGE TO BE COMPLETED BY AFRL EDO

AFRL IR Protocol Number: FWR20170015R

Exempt Determination Official (EDO) Basis for Determination/Comments:

This project is intent on answering the specific research question: With additional richness and consequently more learning, are unintended OPSEC cues transmitted via a mobile app as compared to traditional work order submission methods? The research team will accomplish this study and answer the research questioned stated above by:

1. Evaluating a smart-phone app for work order generation within an Air Force environment
2. Comparing effectiveness of the smartphone mobile application vs traditional voice-based work order generation.
3. Determining if using the media rich mobile app introduces unintended OPSEC concerns

To conduct these objective and provide insight to the research approximately 30 participants are needed to report on 30 real-world maintenance items (work orders) previously identified by the AFIT facility manager. Work orders generated by each condition will be evaluated by a team of subject matter experts from the civil engineering squadron at Wright Patterson.

This study includes living participants but does not collect data about the participant. Personnel are only necessary to generate work orders either traditionally or via mobile app. Study analysis is then performed on the work orders not the living participants; therefore, The AFRL has determined this study to constitute as "Research Not Involving Human subjects".

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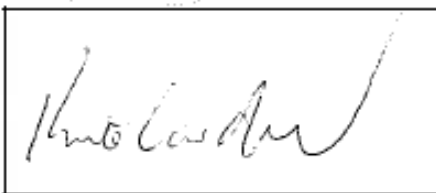
This determination applies only to the requirements of 32 CFR 219, DoDD 3216.2, AFI 40-402, and related human research subject regulations. If this project is a survey, attitude or opinion poll, questionnaire, or interview then consult AFI 38 501 Air Force Survey Program for further guidance. If data is being collected from persons affiliated with the Air Force, approval may need to be obtained from HQ AFPC/DSYS. The Air Force Survey Office may be contacted at af.surveys@us.af.mil. It does not constitute final approval to conduct the test, or serve as a safety or technical review board approval, which should be pursued separately, if necessary (note, AFRL 61-103 v.2). A safety review of the proposed testing procedures may be required. The IRB is not responsible for the oversight of test and evaluation activities. Contact the system safety officer, Mr. Keith Vossler, AFRL/SE, 986-5685 for guidance/ compliance on test and evaluation.

EDO DETERMINATION

Based on the information provided, the EDO reviewer has determined:

- ☐ The activity does not meet the definition of "Research" under the common rule (32 CFR 219).
- ☒ The activity is Research but does not involve "Human Subjects" under the common rule (32 CFR 219).
- ☐ Requires further review by the IRB Chair:
- ☐ The activity appears to be Research which involves Human Subjects under the common rule (32 CFR 219).
 - ☐ The activity appears to involve the use of protected health information (PHI) for research purposes.
 - ☐ The activity appears to involve human subjects per FDA definition and is subject to FDA regulations.

EDO or IRB Reviewer Signature



Date

22 Nov 2016

EDO Expiration Date

N/A IRB Chair

Effects of Mobile Applications on the Traditional Work Order Submission Process

1. Principal Investigator

Dr. Brent T. Langhals, DSN 785-3636, ext. 7402, AFIT/ENV
brent.langhals@afit.edu

2. Associate Investigators

Capt Victor Guinn, DSN 785-3636, ext. 7402, AFIT/ENV,
victor.guinn@afit.edu

Capt Michael Peterson DSN 785-3636, ext. 7402, AFIT/ENV,
michael.peterson@afit.edu

3. Facility/Contractor

3.1. Sponsor: n/a

3.2. Funding Source and Funding Amount: n/a

3.3. Contract #/CRADA #/Cooperative Agreement #: n/a

3.4. Activity location(s) (where activity will be conducted): Air Force Institute of
Technology Campus, Wright-Patterson AFB

4. Conflicts of Interest

None

5. Background Information and Scientific Rationale

An unfortunately reality is that components of Air Force facilities are failing on a daily basis. Base civil engineering squadrons frequently maintain long lists of pending work orders due to inadequate initial problem or location description resulting in multiple site visits and poor problem diagnosis. Clearly a more efficient method to quickly submit, diagnose, and respond to problems needs to be investigated (ASCE, 2013). With the advent of smartphone technology being available to a majority of the population, many cities in partnership with private companies are developing community request management applications to address similar problems (Rittatore, 2015). The Air Force relevant research question for this study is: "Does a smartphone-based work order submission application based on a civilian model perform better in the categories of problem location and description than using the traditional verbal phone-based work order submission system while also not introducing any additional OPSEC security concerns?"

There are two main objectives required for a successful work order submission: locating the problem and description of the problem (Little, 2010). Geolocation of a problem is accurately determining where each reported problem is located in the physical world (Maguire, Woollett, & Spiers, 2006). If maintenance personnel are unable to locate a reported problem, countless hours could be wasted in tracking down the actual site. Those are hours not spent actually fixing the problem. Frequently the current work order generation process only captures minimal location information. For example, an airman may call the work center to report a light bulb is out on a streetlight on base. Unfortunately the road reported is one mile long and has over 150 street lights. Unless the maintenance team goes out at night, they cannot easily determine which bulb is out. A more accurate problem location

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mechanism would allow maintenance to occur at any time, possible while the crew is already in position with another job instead of requiring a follow-up visit. Similarly, problem description accuracy is the ability of a subject matter expert to diagnose a work order problem based on the information provided by the initial call. Frequently the individual submitting the work order does not have the requisite knowledge to accurately describe the problem, resulting in the work center having to send out a team to assess the problem and then a second team to actually fix the problem. If the original work order had enough information to diagnose the problem, multiple trips may be avoided.

Finally, different forms of communication or communication mediums have varying degrees of richness. According to Daft and Lengel (1986), "information richness is defined as the ability of information to change understanding within a time interval". The "richer" the communication medium, the more effective it is at changing understanding. In other words, the more learning that can be pumped through a medium, the richer the medium. Therefore, based on media richness theory, a mobile application may be considered a "richer" form of communication because it includes written and visual communication methods versus only verbal. With additional richness and consequently more learning, are unintended OPSEC cues transmitted via a mobile app as compared to traditional work order submission methods?

6. Study Objective(s) and Purpose

- 6.1. **Purpose:** Evaluating a smart-phone app for work order generation within an Air Force environment
- 6.2. **Primary Objective:** Effectiveness of the smartphone mobile application vs traditional voice-based work order generation.
- 6.3. **Secondary Objective(s):** Determining if using the media rich mobile app introduces unintended OPSEC concerns

7. Study Design

7.1. Description of Study Design:

This study will ask participants to submit work orders for real-world maintenance issues using a traditional phone based system vs a mobile application loaded on a smartphone. The study will take place in the following three parts:

Part 1: Approximately 30 participants will be escorted around the AFIT complex by the research team to report on 30 real-world maintenance items previously identified by the AFIT facility manager. Examples of these items include broken ceiling tiles, inoperable lights, broken doors...etc. The participants will be randomly assigned to either the traditional (phone call) or test (mobile app) conditions. For the traditional condition, the participants will make a phone call to a simulated work center where the call will be recorded and the work order information collected. Test condition participants will be provided a smartphone with the mobile app already installed. The mobile app will allow the participant to enter text information regarding the maintenance action as well as allow for image uploads. All participants will be trained on their respective reporting

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techniques prior to starting the task. In all, the task is expected to last an average of 45 minutes. See Attachment 5 for a script of the experiment process. Upon completion of the task the participants will be asked to complete a short questionnaire to capture demographic as well other thoughts regarding the task performed. See Attachment 4 for a copy of the questionnaire.

Part 2: After all participants have completed the work order submission task, each work order generated will be evaluated (scored) by a team of subject matter experts from the civil engineering squadron at Wright Patterson AFB. The criteria for evaluation will include rating each work order (both conditions) on a Likert Scale for the following: understanding of the problem, understanding location of the problem, ability to diagnose the problem, and the need to obtain additional information based on the information generated by each technique. Each SME will score each work order individually and the scores for each work order will be averaged for a final score. If major discrepancies in scoring are identified, the team will convene to discuss the reasons.

Part 3: The last part of this study will look at the work orders generated by each condition and determine if any OPSEC critical indicators (CI) were inadvertently collected as part of the work order generation process. AFIT maintains a list of CIs that may have OPSEC implications. For each location a work order is submitted, any potential CIs from the AFIT list that may exist have been identified. That number serves as the denominator for a percentage of critical indicators transmitted through the work order submission process. For example, in one location a ceiling light is not working. Near the site is a SCIF, a bulletin board with mission information posted, a trash can with collection times, and a facility map. Per the AFIT critical indicator list each of these items may present OPSEC indicators. Post-hoc, the number of actual indicators transmitted will be counted and will serve as the numerator in the percentage of CI transmitted. To continue the example, say the image generated by the mobile app for participant 1 captured a picture of the SCIF door and the facility map. For that work order, the percentage of CI transmitted would be scored as 2/4 or 50%. This percentage would be calculated for each work order generated for each condition.

Upon completion of each part of the study, results will be analyzed to determine the effectiveness of the mobile app vs the traditional work order submission process. Additional analysis will also determine if significantly more OPSEC CIs were transmitted using the mobile app process.

8. Subjects

30 subjects will be recruited. The population will include a mix of active duty military, DoD civilians, and DoD contractors (subject to union rules), as well as potentially personnel with no DoD affiliation. Subjects will first be recruited from the population of AFIT students and faculty.

Measures will be taken to ensure that the participants are able to participate in the study and that their designation does not preclude them from participating (i.e., that there are no contractual or

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pending contractual relationships that would create an implied pressure to participate). Also, measures will be taken to work with limits on their participation based on their designation (i.e. that some civilians might only participate during non-duty time, or that participation is not commander-directed for active duty, etc.)

The only physical requirements for inclusion are that participants be able to hold and operate a smart phone.

No special subjects will be involved (45 CFR 46 subparts B-D).

No compensation will be given to the subjects.

The time commitment for each subject will be one approximately 45 minute session.

The principal and associate investigators will recruit subjects in person using snowball sampling.

Age range will be from 22 on up.

9. Experimental Plan

9.1. Equipment:

The only equipment required is a smartphone that will be provided to the participant. The phone will be preloaded with the mobile app. The phone will be used for both condition groups in the study. Participants will be trained on how to use the equipment prior to beginning the study.

10. Risk/Benefit Analysis

10.1. Benefits:

There is no benefit to the subjects, however the information gained through the study may positively impact how work orders are generated and responded to for the Air Force.

10.2. Risks:

This study presents limited physical risk to the subjects typical office work (e.g. eye strain, minimal walking around).

The study presents no known psychological risks that the research team is aware of.

The primary risk involved in this research is the release of personal information from the data collected. Personal information as outlined in Section 3.d will be used to enable contact with participants identified as suitable for further experiments. There is the possibility that the collected demographic information can be correlated to uniquely identify a participant based on the sound of their voice and/or a combination of

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information collected. User information will be stored in an anonymized fashion and we will have a strict policy that no personally identifiable or "anonymized" information shall be released from this corpus. In addition, personal information will be separated from observations, which will not record personally identifiable information.

11. Safety Monitoring and Reporting

The PI will ensure that mishaps or injuries sustained during research will be reported as required pursuant to AFI 91-204.

12. Confidentiality

Subjects' will be asked for their age, AFSC/Job Title, skill level, and pay grade. Each subject will be assigned a numeric ID which will be used to label all data they produce.

The questionnaires, audio recordings and other data produced will be stored in a secure cabinet under the control of the primary investigator. After the raw data has been encoded, the raw data will be destroyed. The raw data will not otherwise be released in any form.

13. Data Management/ Data Sharing Plan

Data collected as part of this study will be secured in a locked cabinet and on a PC located in a locked office when an investigator is not present. There is no plan to share the data outside of the research team. Analysis of the results will be published in peer-reviewed journals or conference proceedings. Further, two theses will include various aspects of the data collected. The principle investigator will manage all data collected at the end of the study until it is ready for destruction.

14. References

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- Little, D. (2010). *CDC 3E651 Operations Management Journeyman*. (S. Glenn, Ed.) (04 ed., Vol. 2). Sheppard Air Force Base, Texas: Air University Air Education and Training Command.
- Maguire, E. A., Woollett, K., & Spiers, H. J. (2006). London taxi drivers and bus drivers: A structural MRI and neuropsychological analysis. *Hippocampus*, 16(12), 1091-1101. <http://doi.org/10.1002/hipo.20233>.
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from <http://gov.seeclickfix.com/customers/corona-ca>.

15. Attachments

1. Informed Consent Document
2. Current Curriculum Vitae of investigators
3. Human Subjects Training Certificates of investigators
4. Post-study Questionnaire
5. Study Script

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Appendix G: Informed Consent Form

**Consent to Participate in Research
For
Effects of Mobile Applications on the Traditional Work Order Submission Process**

Principal Investigator: Dr. Brent T. Langhals, DSN 785-3636, ext. 7402, AFIT/ENV
brent.langhals@afit.edu

Associate Investigators: Capt Victor Guinn, DSN 785-3636, ext. 7402, AFIT/ENV
victor.guinn@afit.edu

Capt Michael Peterson DSN 785-3636, ext. 7402, AFIT/ENV
michael.peterson@afit.edu

1. INTRODUCTION

You are being invited to take part in a research study. The information in this form is provided to help you decide whether or not to take part. Study personnel will be available to answer your questions and provide additional information. If you decide to take part in the study, you will be asked to sign this consent form. A copy of this form will be given to you. Your participation will occur at Wright Patterson AFB, OH.

2. PURPOSE

The purpose of this study is to determine if using a mobile application to collect civil engineering work requests is more or less efficient, effective, and secure than the current collection process. The intent of the study is to look at the pros and cons of incorporating a mobile application into the current work order submission process.

The time requirement for each volunteer subject is anticipated to be a total of 30 consecutive minutes. It is expected that approximately 60 subjects will be enrolled in this study. Subjects must be able to speak, read, write, and understand English, talk on a telephone, operate an Android or IOS device, and see differences in colors.

3. PROCEDURES

If you decide to participate, you will be asked to complete a short post experiment questionnaire that will capture some demographic information and ask questions that cannot be revealed until after you participate in the experiment. Completing the questionnaire is completely voluntary. The demographic questions include the following:

How old are you?
What is your AFSC/Job Title
What is your skill level?
What is your pay grade?

As part of the study, you will be asked to find and submit work order data that is located throughout the Air Force Institute of Technology Campus. There will be two types of submission methods: (1) Using a mobile application, (2) Using a telephone to call in work

orders. If you choose to participate, you may be assigned both methods. You will be given a map and instructions that will show you where and how to identify and submit work requests.

Your participation in this study is voluntary. You will not lose any benefit that would normally be entitled if you do not participate or withdraw from the research. You may decide to not begin or to stop the study at any time. If you are a student, your refusing to participate will have no effect on your student status. Also, any new information discovered about the research will be provided to you. This information could affect your willingness to continue your participation and will therefore be furnished to you.

4. POTENTIAL RISKS and/or DISCOMFORTS

The tasks that you will be doing have no known safety or psychological risks. Although we have tried to avoid risks, if any discomfort occurs you can stop participating immediately.

5. PREGNANCY RISKS

There are no precautions for female subjects or subjects who are or may become pregnant during the course of this study.

6. BENEFITS

If you agree to take part in this research study there may be no direct benefit to you. However, the information learned from this study may someday help us improve the work order submission process.

7. COSTS

There will be no cost to you for the research study.

8. ALTERNATIVES TO PARTICIPATION

Your alternative is to choose not to participate in this research study. Refusal to participate will involve no penalty or loss of benefits to which you are otherwise entitled. You may discontinue participation at any time without penalty or loss of benefits to which you are otherwise entitled. You must notify one of the investigators of this study to discontinue.

9. YOUR PARTICIPATION IS VOLUNTARY

The decision to participate in this research is voluntary on your part. No one may coerce or intimidate you into participating in this program. Participate only if you want to. Dr Brent T Langhals, or an associate, should adequately answer all questions you have about this study, your participation and the procedures involved. If you have any further questions, Dr Langhals can be reached at (937) 255-3636 x7402. Dr. Langhals, or an associate will be available to answer any questions concerning procedures throughout this study. You may withdraw from this research study at any time without penalty.

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If significant new findings develop during the course of this research, which may relate to your decision to continue participate or may affect the risk involved, you will be informed. Additionally, the investigator or Research Monitor of this study may terminate your participation in this study if she or he feels this to be in your best interest. If you have any questions or concerns about your participation in this study or your rights as a research subject, please contact the AFRL IRB at (937) 904-8100 or AFRL.IR.ProtocolManagement@us.af.mil.

If you are removed from the study, the study investigator will contact you to answer any questions you may have.

10. COMPENSATION

If you are active duty military you will receive your normal active duty pay. Additionally, as a courtesy you will be offered food and beverage after to you participate in this study.

11. RESEARCH-RELATED INJURY

Your entitlements to medical and dental care and/or compensation in the event of injury are governed by federal laws and regulations. If you desire further information you may contact the legal office (711 HPW/JA, 986-5666 at Wright-Patterson AFB). In the event of a research related injury, you may contact the Principal Investigator, Dr Brent T. Langhals, of this research study at (937) 255-3636).

12. SIGNIFICANT NEW FINDINGS

You will be told by the study investigator or study staff if new information becomes available that might affect your choice to stay in the study.

13. CONFIDENTIALITY

Records of your participation in this study may only be disclosed according to federal law, including the Federal Privacy Act, 5 U.S.C. 552a, and its implementing regulations and the Health Insurance Portability and Accountability Act (HIPAA), and its implementing regulations, when applicable, and the Freedom of Information Act, 5 U.S.C. Sec 552, and its implementing regulations when applicable.

Your personal information will be stored in a locked cabinet in an office that is locked when not occupied. Electronic files containing your personal information will be password protected and stored only on a secure server. Organizations that may look at and/or copy your medical and/or records for research oversight, quality assurance and data analysis include:

- the researchers named above,
- the study's Research Monitor or Consultant,
- the AFRL Wright Site IRB,
- the Air Force Surgeon General's Research Compliance office,
- the Director of Defense Research and Engineering office or
- other IRB(s) involved in the review and approval of this protocol.

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You will be identified by a code, and personal information from your records will not be released without your written permission unless required for military personnel. Information related to health and fitness for duty may be required to be reported to appropriate medical or command authorities. Complete confidentiality for military members cannot be promised. You will not be identified in any publication or in the sharing of your data about this study.

Your participation in this study may be audio recorded. The purpose of these recordings is capture a typical work order submission via telephone to then compare with work orders submitted via a mobile app.

Your personal information will be stored in a locked cabinet in an office that is locked when not occupied. Electronic files containing your personal information will be password protected and stored only on a secure server. It is intended that the only people having access to your information will be the researchers named above, the AFIT IRB or any other IRB involved in the review and approval of this protocol. When no longer needed for research purposes your information will be destroyed in a secure manner (shredding).

Complete confidentiality cannot be promised, in particular for military personnel, whose health or fitness for duty information may be required to be reported to appropriate medical or command authorities. If such information is to be reported, you will be informed of what is being reported and the reason for the report.

14. PRIVACY ACT

Personal Identifiable Information to be obtained for this study includes gender, job title, AFSC, skill level, age, and experience. Signing this document in no way alters your ability to obtain medical treatment that is not part of this study. If your data is disclosed by the investigator to one of the parties listed above, those parties may pass on your data without further notification to you. Data collected in the course of this study may be withheld from you by the investigator for the duration of the study. If withheld, your data will be released at the conclusion of the study.

15. STUDY PARTICIPATION AGREEMENT/CONSENT

Taking part in this research study is completely voluntary. Your signature below shows that:

- You agree to be in this study
- The researcher has explained the study to you and you have read and understand the information you have been given
- You were given the opportunity to ask questions about the study and all of your questions have been answered to your satisfaction
- You understand that signing this consent does not take away any of your legal rights

You will be given a copy of this signed consent form for your records

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Volunteer Signature _____ Date _____

Volunteer Name (printed) _____

Advising Investigator Signature _____ Date _____

Investigator Name (printed) _____

Witness Signature _____ Date _____

Witness Name (printed) _____

Privacy Act Statement (if applicable)

Authority: We are requesting disclosure of personal information. Researchers are authorized to collect personal information on research subjects under The Privacy Act-5 USC 552a, 10 USC 55, 10 USC 8013, 32 CFR 219, 45 CFR Part 46, and EO 9397, November 1943.

Purpose: It is possible that latent risks or injuries inherent in this experiment will not be discovered until some time in the future. The purpose of collecting this information is to aid researchers in locating you at a future date if further disclosures are appropriate.

Routine Uses: Information may be furnished to Federal, State and local agencies for any uses published by the Air Force in the Federal Register, 52 FR 16431, to include, furtherance of the research involved with this study and to provide medical care.

Disclosure: Disclosure of the requested information is voluntary. No adverse action whatsoever will be taken against you, and no privilege will be denied you based on the fact you do not disclose this information. However, your participation in this study may be impacted by a refusal to provide this information.

TITLE/PROTOCOL & VERSION NUMBER &
APPROVAL PERIOD TO BE ADDED BY IRB
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Air Force Institute of Technology

The AFIT of Today is the Air Force of Tomorrow.





Smartphone Based Infrastructure Work Order Submission CES SQ Coding Brief



Problem Summary

The AFIT of Today is the Air Force of Tomorrow.



- Current Air Force Work Order Submission framework is a 1950's solution to 2016 problems.
 - Information largely limited to verbal/text
 - Work order duplication is a constant problem
 - Bases are breaking faster than we can fix them, we need the ability for CE to ID critical items, not a facility managers interpretation of what critical is

*Air University: The Intellectual and Leadership Center of the Air Force Aim
High...Fly - Fight - Win*

2



What We Are Researching

The AFIT of Today is the Air Force of Tomorrow.



- Will smartphone based work order submission systems allow a unexperienced user to transmit information at the level of an expert with minimal training, out performing traditional verbal phone based submission systems when examining, a **Civil Engineering craftsman understanding of the problem**, and the **quality of information** transmitted.

The purpose behind these questions is to determine what information you need to solve a infrastructure problem, and to direct research as to how we can collect it.

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3



What We Did

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- We created a course at AFIT consisting of 29 pre-existing broken facility items, that would be mostly DSW type work.
 - We then took 20 people through the course and let them submit traditional verbal work requests.
 - We then took another 20 people through the course and gave them a smartphone application we created at AFIT that allowed them to not only describe the problem but take a picture of it as well




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Verbal Submission Process

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- All users were asked the following questions, and a computer recorded their verbal response.
 - What is your subject number?
 - What is your location?
 - What is the infrastructure problem that you are trying to submit?

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Info From Verbal Submission

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Below are examples of some of the verbal transcripts

- Subject 23 I am outside of building 643 on the interior kind of court courtyard side of the door that goes into 643 and outside of that door there is an **overhead light** the second one from that door the **overhead light cover is broken**. I can't tell if it doesn't appear. It looks like the light, maybe broken as well
- Subject number 23 I'm building 642 in the loading dock area. I'm out of the elevator machine room 126 there is an **overhead light** that the **bulbs are not are not working** very well. They are lit but they are not lit as well as the other lights.
- subject 26 building to first floor loading dock **overhead light** on left hand side is out.
- Subject number 29... next Einstein's bagels just next to room 126 elevator machine room. Looking at one of those **overhead lights** is **flickering** and needs replaced.
- Subject number 29. I'm outside of building 643 the CE school house, at AFIT. I'm reporting **one of the light**, it's at the main lobby where all the windows are. **One of the lights is busted, looks like it's been busted for a long time.**
- My subject number is 24 my location is. Building 640 3rd floor outside of room 302 there is a **Bulletin board** display in the hallway and the **lights** above the Bulletin board are **not working**.

As can be seen from the above, they lack details needed for repair

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Mobile Submission Process

The AFIT of Today is the Air Force of Tomorrow.

- We created a mobile application to mimic current commercially available applications



- Please note that the mobile application has the following features that were disabled for the test.
 - Audio recording
 - Video recording
 - Multiple photo submission
 - Live DSW updates
 - Live text communication with operators, and craftsmen.

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Info From Mobile Application

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Below are examples of info from the mobile application, of the same items described verbally on the previous slides. Notice the higher level of information transmitted.







Info From Mobile Application

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Below are some additional examples of info from the mobile application.







What We Need From CE Shops

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- What information would help you diagnose, and system failure prior to leaving the shop?
- What information did we not gather that you would need to accomplish the job faster? Like model, size, plate #...ect.
- Are we researching the right stuff?




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Appendix I: Words Removed From Data Set Used in Word Analysis

a	because	different	go	insofar
a's	become	do	goes	instead
able	becomes	does	going	into
about	becoming	doesn't	gone	inward
above	been	doing	got	is
according	before	don't	gotten	isn't
accordingly	beforehand	done	greetings	it
across	behind	down	h	it'd
actually	being	downwards	had	it'll
after	believe	during	hadn't	it's
afterwards	below	e	happens	its
again	beside	each	hardly	itself
against	besides	edu	has	j
ain't	best	eg	hasn't	just
all	better	eight	have	k
allow	between	either	haven't	keep
allows	beyond	else	having	keeps
almost	both	elsewhere	he	kept
alone	brief	enough	he's	know
along	but	entirely	hello	knows
already	by	especially	help	known
also	c	et	hence	l
although	c'mon	etc	her	last
always	c's	even	here	lately
am	came	ever	here's	later
among	can	every	hereafter	latter
amongst	can't	everybody	hereby	latterly
an	cannot	everyone	herein	least
and	cant	everything	hereupon	less
another	cause	everywhere	hers	lest
any	causes	ex	herself	let
anybody	certain	exactly	hi	let's
anyhow	certainly	example	him	like
anyone	changes	except	himself	liked
anything	clearly	f	his	likely
anyway	co	far	hither	little
anyways	com	few	hopefully	look
anywhere	come	fifth	how	looking
apart	comes	first	howbeit	looks
appear	concerning	five	however	ltd
appreciate	consequently	followed	i	m
appropriate	consider	following	i'd	mainly
are	considering	follows	i'll	many
aren't	contain	for	i'm	may
around	containing	former	i've	maybe
as	contains	formerly	ie	me
aside	corresponding	forth	if	mean
ask	could	four	ignored	meanwhile
asking	couldn't	from	immediate	merely
associated	course	further	in	might
at	currently	furthermore	inasmuch	more
available	d	g	inc	moreover
away	definitely	get	indeed	most
awfully	described	gets	indicate	mostly
b	despite	getting	indicated	much
be	did	given	indicates	must
became	didn't	gives	inner	my

myself	particular	so	this	we're
n	particularly	some	thorough	we've
name	per	somebody	thoroughly	welcome
namely	perhaps	somehow	those	well
nd	placed	someone	though	went
near	please	something	three	were
nearly	plus	sometime	through	weren't
necessary	possible	sometimes	throughout	what
need	presumably	somewhat	thru	what's
needs	probably	somewhere	thus	whatever
neither	provides	soon	to	when
never	q	sorry	together	whence
nevertheless	que	specified	too	whenever
new	quite	specify	took	where
next	qv	specifying	toward	where's
nine	r	still	towards	whereafter
no	rather	sub	tried	whereas
nobody	rd	such	tries	whereby
non	re	sup	truly	wherein
none	really	sure	try	whereupon
noone	reasonably	t	trying	wherever
nor	regarding	t's	twice	whether
normally	regardless	take	two	which
not	regards	taken	u	while
nothing	relatively	tell	un	whither
novel	respectively	tends	under	who
now	right	th	unfortunately	who's
nowhere	s	than	unless	whoever
o	said	thank	unlikely	whole
obviously	same	thanks	until	whom
of	saw	thanx	unto	whose
off	say	that	up	why
often	saying	that's	upon	will
oh	says	thats	us	willing
ok	second	the	use	wish
okay	secondly	their	used	with
old	see	theirs	useful	within
on	seeing	them	uses	without
once	seem	themselves	using	won't
one	seemed	then	usually	wonder
ones	seeming	thence	uucp	would
only	seems	there	v	would
onto	seen	there's	value	wouldn't
or	self	thereafter	various	x
other	selves	thereby	very	y
others	sensible	therefore	via	yes
otherwise	sent	therein	viz	yet
ought	serious	theres	vs	you
our	seriously	thereupon	w	you'd
ours	seven	these	want	you'll
ourselves	several	they	wants	you're
out	shall	they'd	was	you've
outside	she	they'll	wasn't	your
over	should	they're	way	yours
overall	shouldn't	they've	we	yourself
own	since	think	we'd	yourselves
p	six	third	we'll	z

zero	area	make	need	near
wont	two	back	front	will
new	permit	remov	repair	install
section	open	entrance	locat	secur
need	check	room	dig	rpl
come	office	unit	work	turn
replac	broken	side	rplc	broken
side	rplc	come	need	build
cut	entranc	secur	close	outsid
request	shop facil	fix	remov	get
issu	inop	rpr	bldg	

Appendix : J Post Course Questionnaire Responses

Subject Number	Direction	Age	AFSC/JobTitle	AFSC Short	Civil Engineer	Pay Grade	Gender	Education	Mobile Application User Experience 1-5 Scale 5 = Pleasant	Mobile Application Photo Used To Document Location	Color Blind	Self-Evaluated Facility Diagnostic Skill Level	Work Order Submission Method Used
1	Forward	28	32E3G/General Civil Engineer	32E	T	O-3	Male	Bachelor degree	4	Yes	No	3	Mobile application
2	Forward	26	32E3G Civil Engineer	32E	T	O-3	Male	Masters Degree			No	2	Call-in Method
3	Reverse	26	32E3G/Civil Engineer	32E	T	O-3	Male	Bachelor degree			No	2	Call-in Method
4	Reverse	28	32E	32E	T	O-3	Male	Bachelor degree	5	Yes	No	4	Mobile application
5	Forward	27	32E/AFIT Student	32E	T	O-3	Male	Bachelor degree			No	3	Call-in Method
6	Forward	29	32E3 civil engineer	32E	T	O-3	Male	Bachelor degree	5	Yes	No	4	Mobile application
7	Reverse	25	0855 / Electronics Engineer	62E	F	GS-09	Male	Bachelor degree			No	2	Call-in Method
8	Reverse	25	65W	65W	F	O-2	Male	Bachelor degree	4	Yes	No	1	Mobile application
9	Reverse	32	62E/Developmental Engineer	62E	F	O-3	Male	Bachelor degree			No	2	Call-in Method
10	Forward	29	21R/Logistics Readiness Officer	21R	F	O-3	Male	Masters Degree	5	Yes	No	1	Mobile application
11	Forward	29	32E/Student	32E	T	O-3	Male	Bachelor degree			No	4	Call-in Method
12	Reverse	45	Teacher	81T	F	CIV	Male	Masters Degree	5	Yes	No	2	Mobile application
13	Forward	26	32E	32E	T	O-2	Male	Bachelor degree			No	4	Call-in Method
14	Reverse	25	32E	32E	T	O-2	Male	Bachelor degree	4	Yes	No	3	Mobile application
15	Reverse	24	62E1B Astronautical Engineer	62E	F	O-1	Male	Bachelor degree			No	2	Call-in Method
16	Reverse	28	32E2E Civil Electrical Engineer	32E	T	O-2	Male	Bachelor degree	5	Yes	No	3	Mobile application
17	Forward	26	32E3B	32E	T	O-2	Male	Bachelor degree			Yes	3	Call-in Method
18	Reverse	27	Teacher	81T	F	CIV	Female	Masters Degree			No	1	Call-in Method
19	Forward	27	32E3G (Civil Engineer)/Student	32E	T	O-3	Male	Bachelor degree	4	Yes	No	4	Mobile application
20	Forward	27	32E3G/AFIT Student (GEM)	32E	T	O-3	Female	Bachelor degree	4	Yes	No	3	Mobile application
21	Reverse	26	32E/Civil Engineering Officer	32E	T	O-2	Male	Bachelor degree	4	Yes	No	3	Mobile application
22	Forward	33	6C071/Contracting Officer	64P	F	E-7	Female	Bachelor degree	5	Yes	No	3	Mobile application
23	Forward	25	32E3C/Civil Engineer	32E	T	O-2	Male	Bachelor degree			No	4	Call-in Method
24	Reverse	37	62E	62E	F	O-3	Male	Bachelor degree			No	1	Call-in Method
25	Forward	26	32E3G/Civil Engineer	32E	T	O-3	Male	Bachelor degree			No	3	Call-in Method
26	Forward	27	32E3G/AFIT Student	32E	T	O-2	Male	Bachelor degree			Yes	3	Call-in Method
27	Reverse	32	32E/Civil Engineer	32E	T	O-3	Male	Bachelor degree	5	Yes	No	3	Mobile application
28	Reverse	26	32E / Civil Engineer	32E	T	O-2	Male	Bachelor degree	5	Yes	No	3	Mobile application
29	Forward	27	32E	32E	T	O-2	Male	Bachelor degree			No	3	Call-in Method
30	Reverse	26	17S	17S	F	O-3	Male	Bachelor degree	5	Yes	No	1	Mobile application
31	Reverse	25	F15 Depot level maintenance engineer	21M	F	O-2	Male	Bachelor degree			No	2	Call-in Method
32	Forward	29	62E/Developmental Engineer	62E	F	O-3	Male	Bachelor degree	3	Yes	No	3	Mobile application
33	Reverse	36	21M, Mx Officer	21M	F	O-4	Male	Bachelor degree	5	Yes	No	2	Mobile application
34	Reverse	32	21M Munitions and Missile Maintenance/Student	21M	F	O-4	Female	Masters Degree			No	2	Call-in Method
35	Forward	24	62E	62E	F	O-1	Male	Bachelor degree			No	3	Call-in Method
36	Forward	39	62E	62E	F	O-3	Male	Bachelor degree	4	Yes	No	3	Mobile application
37	Reverse	24	Student/Contract Researcher	62E	F	KTR	Male	Bachelor degree			No	1	Call-in Method
38	Forward	35	21R logistics readiness Officer	21R	F	O-2	Male	Masters Degree	4	Yes	No	2	Mobile application
39	Reverse	27	62E	62E	F	O-2	Male	Bachelor degree	5	Yes	No	2	Mobile application
40	Forward	23	62EXG currently a student	62E	F	O-1	Male	Bachelor degree			No	3	Call-in Method

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14. ABSTRACT Air Force Civil Engineers (CE) require a constant stream of current information about facility problems to diagnose, prioritize, repair and maintain the large infrastructure inventory needed for day to day operations. Controllers currently rely on information collected via verbal submissions from facility owners, from which they create text based work orders to repair infrastructure issues. Verbal submission is limited in its ability to diagnose the growing, and increasingly complex facility infrastructure systems. Newly developed smartphone-based work order submission may hold the key to this problem. To test if smartphone-based submission systems generate more useful information, an experiment was designed to test submission systems using simulations of real-world, historically based maintenance scenarios. A course of broken infrastructure was laid out and test subjects asked to submit work orders utilizing either verbal or smartphone-based submission systems. Analysis revealed that the smartphone system had the greatest information usefulness, mitigated the CE organizational language barrier, and allowed any individual regardless of facility diagnostic experience to submit a work order at the level of an expert. These results show that smartphone technology is capable of not only quickly being able to relay more pertinent information to a CE craftsman, but in the hands of any Airmen the system allows them to freely communicate with CE craftsmen as if they were facility diagnostic experts themselves.					
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