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A Change Management Approach to Enhance Facility Maintenance Programs

Stanton P. Brown

A CHANGE MANAGEMENT APPROACH TO ENHANCE FACILITY

MAINTENANCE PROGRAMS

THESIS

Stanton P. Brown, Captain, USAF

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DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY

AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

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Stanton P. Brown, BS

Captain, USAF

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Stanton P. Brown, BS

Captain, USAF

Approved:

//signed//	17 March 2014
Alfred E. Thal, Jr., PhD (Chair)	Date
//signed//	11 March 2014
Alan R. Heminger, PhD (Member)	Date
//signed//	11 March 2014
Vhance V. Valencia, PhD, Maj, USAF (Member)	Date
//signed//	11 March 2014
Bert D. Liddell, Capt, USAF (Member)	Date

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Abstract

A recent study assigned it a grade of D+ on the nation's public infrastructure, revealing that inadequate attention has been focused on maintaining these assets. Because of this poor asset condition, many organizations tend to respond to maintenance in a reactive mode; however, relying on corrective maintenance leads to increased maintenance costs due to unplanned downtime, increased labor costs, and inefficient use of personnel. To address this situation, asset management (AM) principles should be employed to transition organizations towards a more proactive maintenance program. Unfortunately, it has been shown that two-thirds of the organizations have failed to implement general change efforts. Therefore, an organizational change management framework should be followed to implement a change that will successfully transition organizations from reactive to proactive maintenance.

This research effort focuses on building the framework for a change message to help Air Force decision-makers implement new Information Technology (IT) that addresses key AM principles such as asset condition and remaining service life. A Delphi study was utilized to elicit expert field knowledge on facility maintenance and respective IT. Results from the study, combined with guidance from the literature, helped formulate a change message for the implementation of BUILDER™, which will enable a proactive maintenance paradigm.

Acknowledgments

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I. Introduction

"The Only Thing That Is Constant Is Change" – Heraclitus

Every year, organizations continue to evolve to stay competitive, increase profit, or increase efficiencies. In the United States, infrastructure management is one specific area that is continually evolving. Recently, the American Society of Civil Engineers (2013) assessed a grade of D+ for the nation's public infrastructure. This realization identifies a true need for a major change in infrastructure asset management (AM) techniques. However, one study shows that only one-third of the organizations that went through a change effort were actually successful (Meany & Pung, 2008).

In particular, the Air Force manages over 64,000 infrastructure assets valued at 254.8 billion dollars (Department of Defense, 2011), and in 2012, 2.8 billion dollars was spent on sustainment, restoration, and modernization of these assets (Department of Defense, 2013). Furthermore, recent guidance mandates a major change that requires the utilization of a new information technology (IT) system called BUILDER™ (Kendall, 2013). The BUILDER™ program is a web-based decision support system for use by infrastructure asset managers to determine and plan the maintenance needs for their facilities (BUILDER, 2013). This research focuses on Air Force facility maintenance programs and implementation of BUILDER™ using an organizational change management approach.

Background

Literature shows that improper facility maintenance management can lead to premature degradation (Hatry & Liner, 1994; Ottoman, Nixon, & Lofgren, 1999a; Neelamkavil, 2009). One common outcome from an organization that practices improper maintenance on their infrastructure is that maintenance technicians are most certainly reacting to facility maintenance requirements. In this type of AM organization, the technicians are relying on corrective maintenance rather than preventive or condition-based maintenance.

Furthermore, relying solely on a corrective maintenance program can result in deferred maintenance with significantly higher costs (Sullivan, Pugh, Melendez, & Hunt, 2010). According to Vanier (2001:7), when scheduled "maintenance is not completed in year one, then the costs of [deferred] maintenance, repair, or replacement are higher in subsequent years." Component degradation curves, as shown in Figure 1, provide a visual tool to facilitate an understanding of this phenomenon. Decisions to delay scheduled maintenance to some future time might result in a component's condition index (CI) to degrade to a low level of performance and the action to restore a component's condition would change from maintenance to rehabilitation. Such repairs can cost considerably more to return the component back to a good or excellent CI. However, when maintenance is proactively performed at scheduled intervals, the component service life can be greatly extended as shown in Figure 2. More importantly, this proactive mode allows managers to accurately plan for future resource needs.

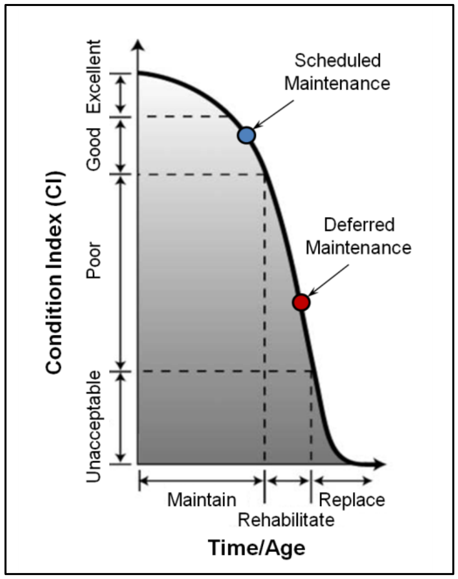


Figure 1. Component Degradation Curve (Dornan, 2002)

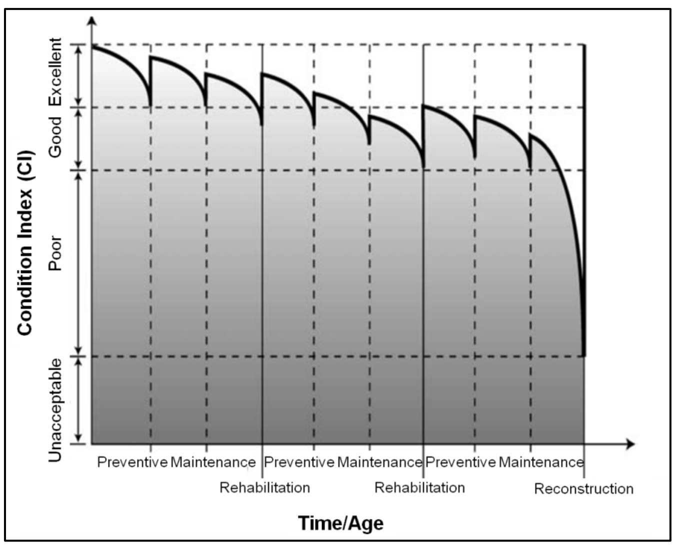


Figure 2. Proactive Maintenance Degradation Curve (Dornan, 2002)

For those organizations that desire to transition towards a proactive facility maintenance program, managers should pursue the principles within facility AM. AM is an emerging field that aids decision-makers in prioritizing the items within their asset portfolio that require attention and funding. An AM mindset is also crucial to enable the transition from reactive to proactive maintenance. Vanier (2001) constructed a foundation for AM, which focuses on six areas:

1. Identify a comprehensive asset portfolio.
2. Calculate each asset's worth.
3. Identify each asset's deferred maintenance.
4. Perform asset condition assessments.
5. Calculate an asset's remaining service life.
6. Prioritize assets for maintenance execution.

Organizations must address each area to leverage the ability to manage their assets in a proactive capacity. However, the transition from a predominantly reactive maintenance program to a proactive one can be a daunting task for any organization.

Changing a facility maintenance program requires explicit attention to the implementation process. In general, many change initiatives are unsuccessful in part due to failures to change the organizational culture, lack of integration, lack of commitment of senior management, and lack of leadership (Arora & Kumar, 2000). To address change failures, an original change management concept was developed that involves unfreezing the organization from the status quo, implementing the intended change, and then re-freezing the organization with the new vector (Lewin, 1947). Since Lewin's findings, many variations of change implementation models have been developed to aid senior managers, or change agents (Harrison & Pratt, 1993; Kotter, 1995; George & Jones, 2001; Armenakis & Harris, 2002; Fernandez & Rainey, 2006).

Technological advancements have produced many IT programs that will assist organizations proceeding through a change initiative. Specific to facility maintenance, Computerized Maintenance Management Systems (CMMS) have been developed to track and manage asset inventories, conditions, service life, and other criteria essential for effective decision-making. In particular, the U.S. Army Corps of Engineers developed a program called BUILDER™, which utilizes "inventory information to associate key life-cycle attributes, including replacement costs, expected service lives, and component importance factors" (Grussing, Dilks, & Walters, 2011:1). This program analyzes facility components such as roofs, utilities, and foundations to generate individual component conditions, which combine together to produce a comprehensive Building Condition Index (BCI). Not only does BUILDER™ help address focus areas in AM, but it also supports a transition from reactive to proactive facility maintenance programs.

Specific to the Air Force, maintenance technicians in Civil Engineer (CE) squadrons are continually tasked with quick response work requests. Some of these work requests involve reactive maintenance actions, but other requests tend to be less trivial and more along the lines of visual enhancement of non-critical components such as carpet or paint. These quick response task actions require technician to divert attention away from other planned infrastructure inspection and maintenance actions. Another aspect that affects the technician's ability to manage facility maintenance is the constant deployment cycle where up to 25% of one unit can be deployed at any one point (Byers, 2012). Whether deployed overseas or training at home station in preparation for a deployment, a crucial amount time is diverted away from facility maintenance thus placing the facility maintenance programs in a reactionary mode.

Problem Statement

This research effort originates from recent guidance from the Office of the Deputy Under Secretary of Defense (ODUSD). Inconsistencies currently exist in facility inspection practices throughout the Department of Defense (DoD), and in an effort to standardize facility condition reporting, the ODUSD is requiring the entire DoD to utilize BUILDER™ (Kendall, 2013). This standardization will provide consistent budgetary criteria and add credibility to the DoD's overall asset management program. However, implementing BUILDER™ not only requires the adoption of AM principles to enable the organizational shift from reactive-to-proactive facility maintenance, but it also represents a comprehensive change implementation strategy.

Research Objective and Investigative Questions

The objective of this research is to determine how the Air Force CE leadership can efficiently implement BUILDER™ to employ AM principles and meet the needs of facility maintenance practitioners. While BUILDER™ is a powerful facility condition analysis tool, it is necessary to first establish AM-focused facility maintenance doctrine and a change message to realize the program's benefits. Therefore, the following investigative questions are addressed by this research effort.

1. What tactics and strategies can Air Force CE leadership employ to ensure a successful adoption and long-term use of BUILDER™?
2. According to Air Force CE base-level Subject Matter Experts (SMEs), what defines a successful facility maintenance program?
3. What is the gap between current Air Force facility maintenance programs and an ideal successful facility maintenance program?

4. What is required from a conventional CMMS to meet SME expectations for a successful facility maintenance program?

These questions are organized in an organizational change style in that they identify a desirable end state solution, issues that are currently affecting programs, and expectations of IT systems. It is also important to identify strategies that can assist the Air Force Civil Engineer Center (AFCEC) and base-level CE leadership in developing doctrine to incorporate BUILDER™ into daily facility maintenance operations.

Research Approach

This research effort involves two steps. First, a Delphi study is employed to elicit and consolidate SME opinions on facility maintenance criteria. The Delphi method utilizes numerous questionnaire rounds to capitalize on a group think process. The second step of the research involves incorporating SME input and change management methods to develop a change message. This message addresses five key areas: 1) why the change or new process is needed, 2) confidence in the organization's capability to implement a new process, 3) how the new process meets the organization's needs, 4) support from upper management, 5) and how the new process will benefit individual members (Armenakis & Harris, 2002).

Assumptions and Limitations

BUILDER™ is being implemented in the Air Force in conjunction with another new Next Generation (NextGen) IT tool called Tririga which combines three aging IT systems currently in use. While implementing one new program can be difficult in itself, implementing two new systems together could present further complications for either or both systems due to change recipient reactions to the events (Oreg, Vakola, & Armenakis, 2011). Efforts are currently focused on creating a linkage between Tririga and BUILDER™; therefore, an assumption for this research project is that a linkage will be developed, thus increasing the effectiveness of BUILDER™ in the Air Force.

Additionally, the AFCEC began the initial implementation phase during the early stages of this research effort. While the outcome of this research was originally intended to help decision-makers to develop an implementation plan, it now provides validation for some of the current actions. However, the research outcome and can still be utilized during the future implementation process.

Overview

This Thesis Document follows the traditional five-chapter format. Chapter II consists of a literature review that provides a foundation on asset management concepts with additional focus on facility condition analysis, CMMS, and change management principles. Chapter III presents the methodology employed in the research, to include the Delphi study and change message development. Chapter IV includes the analysis and results from the Delphi study. The final chapter of this research effort provides the discussion and conclusions, recommendations, and suggestions for follow on research.

II. Literature Review

This chapter provides a knowledge foundation regarding the central topics of this research effort based on existing literature. A discussion on facility maintenance is provided followed by asset management (AM) concepts, which provide the groundwork to understand the importance of proactive facility maintenance. Computerized Maintenance Management System (CMMS) incorporation, specifically BUILDER™ in this research effort, is presented as an aid for decision-makers to transition their programs from reactive to proactive facility maintenance. Finally, organizational change management theory is presented as a method to execute this transition.

Facility Maintenance

Organizations with large facility portfolios quickly understand the importance of facility maintenance. In fact, facility maintenance can constitute up to 80% of the overall life-cycle cost of a facility (Christian & Pandeya, 1997). With life-cycle maintenance costs amounting to this level, along with dwindling budgets, it is easy to understand why decision-makers are increasingly interested in their facility maintenance programs. Therefore, this section of the literature review highlights basic facility maintenance concepts and budget estimation methods.

Facility Maintenance Concepts

Maintenance and repair operations on facilities can be accomplished through a variety of strategies. Regardless of the strategy, the underlying need for facility maintenance is to prolong the life of a facility; otherwise, maintenance neglect will lead to premature failure (Sullivan et al., 2010). Figure 3 explains the scenarios of facility degradation with either normal or no maintenance actions. As shown, lack of maintenance can significantly shorten a facility's service life. Therefore, four common facility maintenance strategies exist to keep facilities operating at a desired performance level: corrective (or reactive) maintenance, preventive maintenance, condition-based maintenance, and reliability-centered maintenance (Dotzlaf, 2009; Sapp, 2013; Sullivan et al., 2010; Bevilacqua & Braglia, 2000).

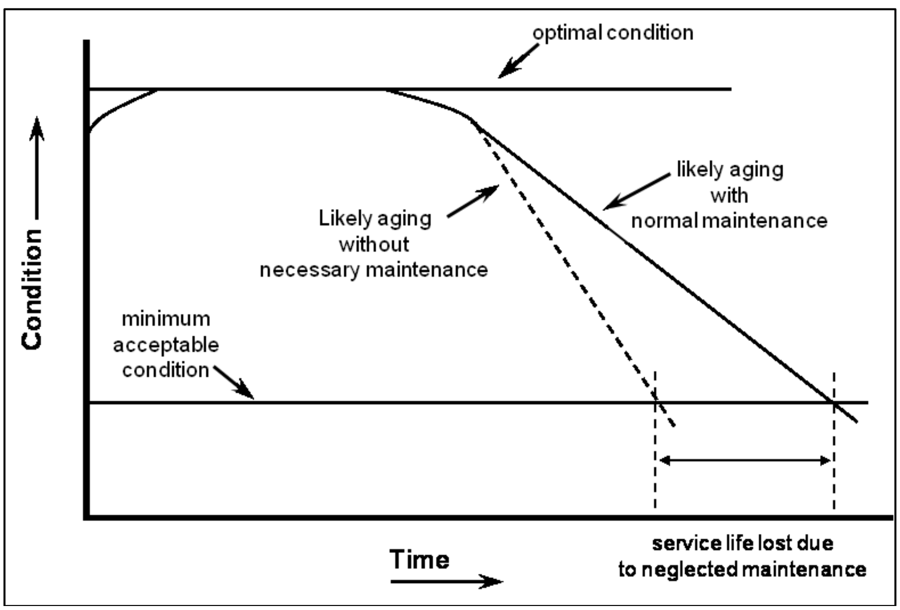


Figure 3. Effect of Timely Maintenance and Repairs on Facility Service Life (National Research Council, 2012)

Corrective Maintenance

Corrective maintenance, also known as reactive maintenance, occurs when maintenance actions are performed once failure occurs. It is also referred to as "the 'run it till it breaks' maintenance mode" (Sullivan et al., 2010:5.2). For large organizations with multiple facilities to manage, corrective maintenance should be 25-30% of the total workload (Cowley, 2013), yet studies show that over 55% of a maintenance program is often associated with reactive maintenance (Sullivan et al., 2010). This situation often stems from simple neglect or even a poor understanding of the asset's performance characteristics. In some cases however, a corrective maintenance approach might be appropriate, such as managing low cost or non-critical components (Pride, 2010).

Sullivan et al. (2010) identify several disadvantages when relying on corrective maintenance: increased cost due to unplanned downtime, increased labor costs (overtime), possible second order affects on other equipment, and inefficient use of personnel. Another disadvantage with corrective maintenance is that the organization focuses little to no attention on asset condition and, although its facilities are currently operating smoothly, has an incorrect perception that these facilities will continue to run smoothly into the future. This inattentiveness and lack of planning introduces deferred maintenance. Deferring too much maintenance can quickly create an environment of reacting continually to problems, which places a vast drain on resources (Dotzlaf, 2009). In addition, once unexpected asset failures begin to occur, facility managers begin to receive criticism from superiors. Moreover, it can be virtually impossible to budget for these unplanned asset failures.

Preventive Maintenance

Preventive maintenance (PM) consists of inspections, adjustment, cleaning, lubrication, and other minor repairs (National Research Council, 2012). PM is based on "a series of time-based requirements that provide a basis for planning, scheduling, and executing scheduled (planned versus corrective) maintenance" (Sapp, 2013:1). A common understanding of PM exists with personal vehicle maintenance where the manufacturer provides schedules for oil, brakes, and system diagnostics.

Sullivan et al. (2010) provide some common advantages and disadvantages of performing PM. Some advantages include increased component life-cycle, energy savings, reduced asset failure, flexibility to adjust maintenance schedules, and cost savings up to 18% over a purely corrective maintenance program. Overall, PM can greatly help managers forecast some of the expected budget requirements. One disadvantage, however, is that PM can be quite labor intensive and, especially within large organizations, technicians can find it difficult to keep up with continual PM. In addition, when an asset is actually operating efficiently, the pre-set PM may result in superfluous maintenance actions. Finally, incidental damage may occur due to increased PM activity with assets. While PM is essential to moving away from a complete reactionary mode, it may not be possible to implement fully due to resource constraints.

Condition-Based Maintenance

Condition-based maintenance (CBM), also known as predictive maintenance, differs from PM in that maintenance is performed based on the asset's condition and not at a pre-planned point in time (Lin, Hsu, & Rajamani, 2002). Understanding the actual condition of the asset will provide managers with an effective metric on when to perform maintenance. Uzarski and Grussing (2006) present a typical condition curve for a facility component at a given time (represented by the dot) as illustrated in Figure 4. Tracking the condition helps decision-makers to have a better understanding of maintenance or repair scopes, as well as the remaining service life. Sullivan et al. (2010) provide an example relating to the personal vehicle where PM would dictate that an oil change is required every 3,000-5,000 miles, yet the engine may not actually require it based on the owner's driving habits. Performing an oil change based on a condition may yield that an oil change is not required until 10,000 miles have been travelled (Sullivan et al., 2010).

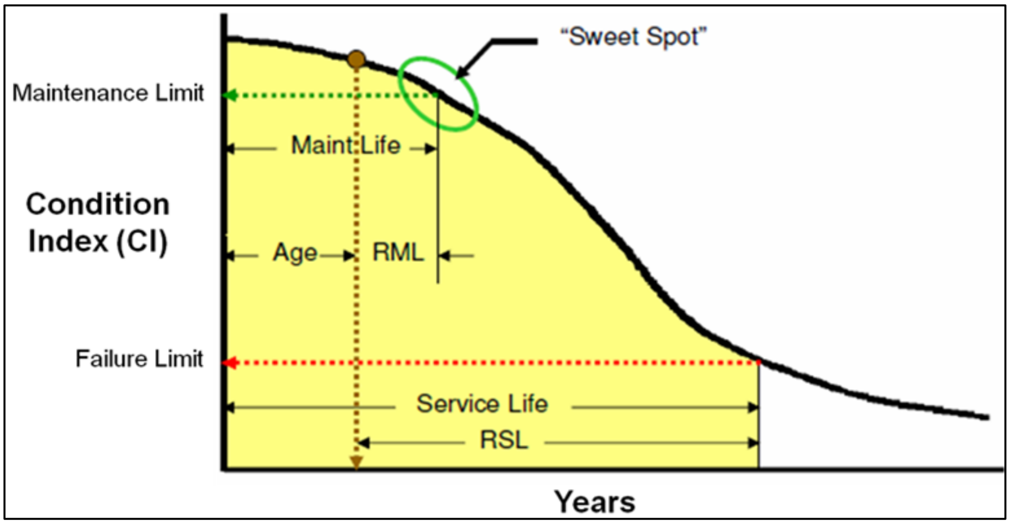


Figure 4. Component Condition Curve (Uzarski & Grussing, 2006)

Similar with PM, Sullivan et al. (2010) provide some common advantages and disadvantages of performing CBM. One advantage is that CBM allows managers to transition to a preemptive maintenance posture, which in turn increases a component's service life. This proactive approach allows for more economical maintenance strategies that will be discussed further in the CMMS section. Other advantages include decreased equipment downtime, decrease in parts and labor costs, better product quality, and energy savings. Significant costs savings of up to 12% can also be achieved by transitioning from a PM only program and up to 40% by transitioning away from reactive maintenance. Senior management, however, may not easily see some of these savings.

Periodic facility inspections provide a snapshot of the various facility components. Typically, inspections are scheduled on a common frequency basis. This pre-determined inspection frequency system results in component inspection regardless of condition, criticality, or component history (Uzarski, Grussing, & Clayton, 2007). Inspections should be performed on specific components at the correct time. For example, there is very little need to inspect a non-critical component that was recently installed; therefore, effort should be directed to critical components that have naturally degraded to a point that is opportune for maintenance. Among many other features, a CMMS will help managers by providing the condition and remaining service life estimates on the various components in a facility (Uzarski & Grussing, 2006). Managers are then able to build a plan for targeted knowledge-based inspections.

Reliability Centered Maintenance

Reliability Centered Maintenance (RCM) is an overarching methodology that combines the three previous approaches. Ultimately, RMC "is the process that is used to determine the most effective approach to maintenance" (NASA, 2000:1-1). Furthermore, RCM typically addresses the operating capability of the facility or system rather than individual components (Sullivan et al., 2010; NASA, 2000; De Carlo & Arleo, 2013; Pride, 2010).

As previously mentioned with inspections, not all components require the same attention. RCM is used to provide a hierarchical system that places facility components into categories to determine an appropriate maintenance method. The RCM approach consists of a general breakdown of the maintenance program, shown in Figure 5, where facility components are categorized to receive reactive, preventive, or condition-based maintenance actions. Top performing facilities typically demonstrate the following maintenance breakdown: less than 10% reactive, 25-35% preventive, and 45-55% condition-based (Sullivan et al., 2010).

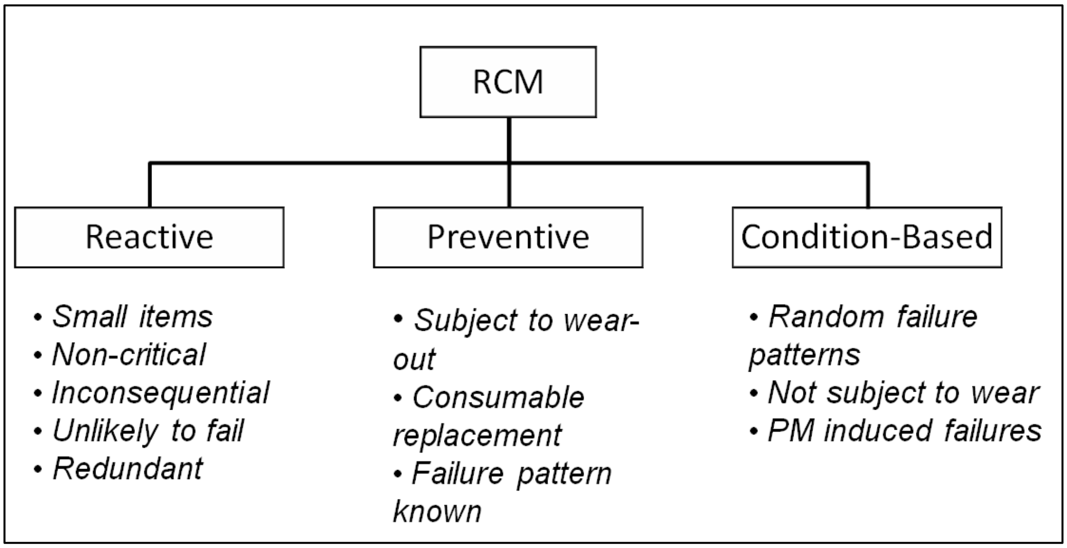


Figure 5. Components of an RCM Program
(Adapted from NASA, 2000)

Facility Maintenance Summary

NASA (2000) provides a general flow chart, shown in Figure 6, that can help decision-makers in any organization, determine which maintenance method best suits the situation. The figure shows four outcomes: run-to-fail (reactive maintenance), develop and schedule interval-based tasks (PM), develop condition-based tasks (CBM), and redesign system or accept risk of failure (NASA, 2000). The last option states that some action, beyond what maintenance can fix, is required.

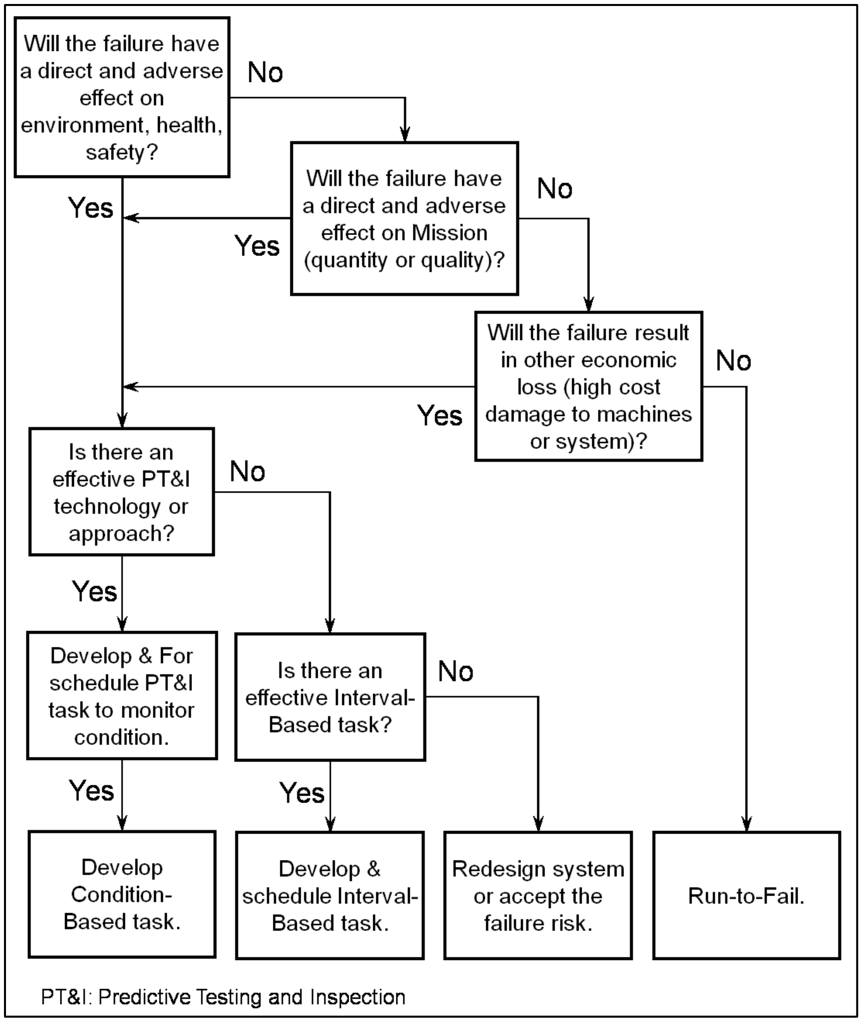


Figure 6. Maintenance Analysis Process
(Adapted from NASA, 2000)

Budget Estimation Methodologies

Large organizations often have numerous considerations when budgets are discussed, and more specifically, when those budgets are reduced. Decision-makers who prioritize where to allocate funds typically focus on conspicuous items that are related to the bottom line or overall mission. Facility maintenance, on the other hand, is often a difficult area to advocate for funds unless something has completely failed (Ottoman et al., 1999a; National Research Council, 2012). Proactive maintenance budget requests tend to be difficult because decision-makers do not easily see the effects. Therefore, it is increasingly important to build a facility maintenance budget that can be easily communicated to decision-makers. Ottoman (1999a) summarizes, through literature research, that Maintenance and Repair (M&R) budget estimations typically fall into one of four general methods: plant value, formula based, life-cycle cost, and condition assessment. Each method has unique characteristics that can be utilized in varying situations.

Plant Value Methods

The plant value methods are based on an understanding that the M&R costs are predicted from the overall asset value (Ottoman, 1997). Barco (1994) presents two models that calculate the plant value: current-plant-value (CPV) which is primarily used in the private sector and plant-replacement-value (PRV) which is more common in the public sector. The CPV is calculated by adjusting the initial capital investment, along with any additions and/or improvements costs, to current year dollars (Barco, 1994). Ideally, this process is completed each year to capture any capital improvements. The PRV, on the other hand, is determined by multiplying a unit cost, based on facility type, by a geographic cost factor (Barco, 1994). This method is popular in that it differentiates the type (e.g., medical, warehouse, office, etc.) and location (e.g., urban or rural, cold or hot climate, etc.) of each facility. The PRV also becomes very useful when the initial construction costs and/or additional capital improvements are unknown.

Formula Based Methods

Formula based methods are mathematical equations that utilize quantifiable physical components of facilities (Ottoman, 1997). To a small degree, PRV fits this type of model except that PRV is used as a value calculation not specifically for M&R. Formula models, however, are specifically used to calculate M&R funding. Cost factors are applied to variables, which include footprint, facility type, and geographic area (Ottoman, 1997).

Life-Cycle Cost Method

The life-cycle cost method is an economic evaluation that consists of the total cost of a facility, in current or future year dollars, to include acquiring, owning, maintaining, and disposing costs (Fuller & Petersen, 1996; Davis, Coony, Gould, & Daly, 2005; Ottoman, 1997). The life-cycle cost analysis is typically geared more towards comparing multiple new construction alternatives that meet the same requirements but with different operation and maintenance costs. However, the same process can be used for M&R estimates on the various components within a facility. This method is more aligned with PM type work where expected maintenance frequencies are known (Ottoman et al., 1999a).

Condition Assessment Methods

The condition assessment method is closely related to condition-based maintenance in that M&R requirements come directly from the actual condition of the facility. This method can be used to identify current M&R requirements and predict the remaining service life of various components (Ottoman, 1997; Grussing, 2012). Both, however, can be utilized together to provide current and future M&R requirements of a facility. This is the central method used in condition curve modeling as shown in Figure 4. A study conducted by Ottoman et al. (1999b) concludes that BUILDER™, which utilizes the condition assessment method, is the best option out of 18 other models they evaluated when life-cycle and maintenance deferral criteria are considered most important. However, due to the amount of data required to operate BUILDER™, it is the least desirable option when the data requirement criteria is considered most important (Ottoman, Nixon, & Chan, 1999b).

Facility Asset Management (AM) Concepts

The AM concept is applicable to any organization that tracks and maintains financially significant items that can include hospital equipment, aircraft, and computer systems, as well as infrastructure components such as roads, utilities, and buildings. The Federal Highway Administration provides one of the more popular definitions:

> Asset Management…is a business process and a decision-making framework that covers an extended time horizon, draws from economics as well as engineering, and considers a broad range of assets. The Asset Management approach incorporates the economic assessment of trade-offs between alternative investment options, both at the project level and at the network or system level, and uses this information to help make cost-effective investment decisions. (FHWA, 1999:5)

Some of the benefits of an effective AM program include "better accountability, sustainability, risk management, service management, and financial efficiency" (NAMS & IPWEA, 2011:1-5). The latter benefit has become increasingly important in the Air Force due to various budget reductions. Underfunding facility maintenance can have consequences such as code failures, health and safety issues, excessive costs (e.g., component replacement, treating symptoms not the cause, and increased utility consumption), low system productivity, and premature loss (Cotts, Roper, & Payant, 2010). When these budget reductions occur in the DoD, a likely area to be affected is facility maintenance; however, without knowledge on the true costs to keep facilities operating, it becomes difficult to defend against the cuts (Yates, 2013).

The Air Force began implementing AM in 2007 for many of the reasons previously stated to build long- and short-term investment execution strategies (HQ USAF, 2014). This shift includes a change to overall business practices as well as implementation of modern information technology (IT) systems. The asset management manual by NAMS & IPWEA (2011) highlights the Air Force as a case study and identifies that some of the reasons behind the transition include:

- Insufficient knowledge or understanding of long-term asset needs or priorities (unknown risk of not funding an asset)
- No standard level of service, performance measures, or targets
- Lack of long-term plans for installation management and development
- Lack of a system to monitor and report installation performance

To develop a successful AM program, Vanier (2001) suggests that facility maintenance program managers focus on six key questions: (1) what do you own, (2) what is it worth, (3) what is the deferred maintenance, (4) what is its condition, (5) what is the remaining service life, and (6) what do you fix first? Additionally, various IT systems can be utilized to strengthen a facility AM program, improve operations, and achieve higher efficiency levels (Basole & Demillo, 2006). Along with a basic definition, the following sections also contain some useful IT tools to aid in facility AM development (Vanier, 2001).

1. What do you own?

Complex campus or city-style asset systems require specific attention to accurately track and identify assets belonging to the organization. An asset hierarchy is used to compile data on facility, asset, and component areas (NAMS & IPWEA, 2011). Figure 7 represents a common hierarchy scheme with two additional levels that group various facilities by type. Von Holdt (2006) further explains each layer of the pyramid. The top two levels provide supplementary detail that groups similar assets. The third level, Facility, is the critical first step in the data acquisition process. Within the facility (e.g., pump station), many assets or systems are required for the functionality of the facility. These systems include the exterior closure, interior construction, electrical, HVAC, and mechanical plant of which, the latter is shown in Figure 7. Each system is then composed of their various components such as a pump in this example.

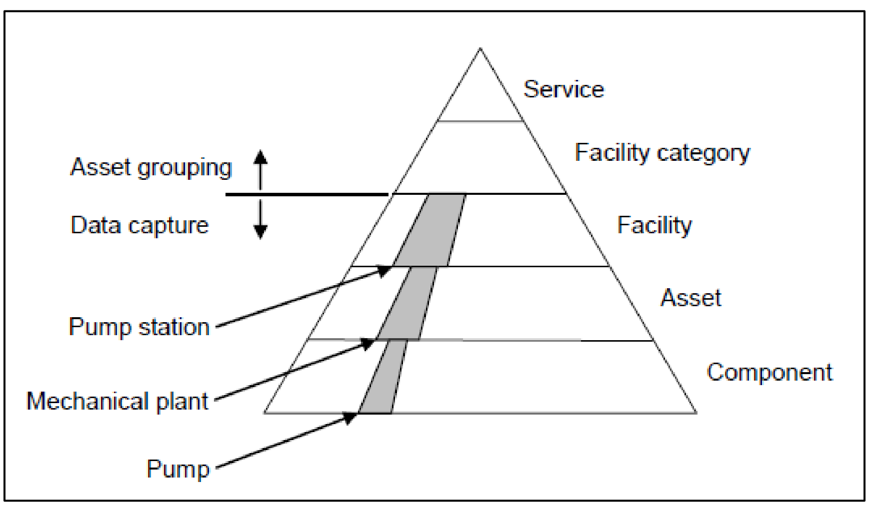


Figure 7. Asset Hierarchy (Von Holdt, 2006)

Various IT systems are available to aid organizations in acquiring, tracking, and managing data for this first step. Geographic Information System (GIS) software is frequently used to geospatially locate assets (Zhang et al., 2009). GIS tools are also capable of tracking data from the top two levels of the pyramid in Figure 7. Once the service and facility category information is added to the facility data, a facility manager can track similar types of facilities and perform network analyses. Even though a GIS can represent an organization's overall asset inventory, it may miss certain aspects within a facility's asset hierarchy. One tool that addresses the lower levels of the pyramid is Building Information Modeling (BIM). BIM is commonly used in large complex facilities such as high-rise buildings and stadiums containing a large number of unique components (Zhang et al., 2009). BUILDER™ is another tool that accurately tracks data at the lower pyramid levels and is capable of calculating component condition and remaining service life.

2. What is it worth?

The overall asset value varies depending on facility type as well as the method used to calculate the value. There are many ways to calculate the value of an asset: historical value, appreciated historic value, CPV (or PRV) as previously discussed, performance-in-use value, deprival cost, and market value (Vanier, 2001). Vanier (2001) provides further detail on each method; for example, the historic value is simply the original capital investment where appreciated historic value brings the original value to current dollars. The performance-in-use value highlights the asset's actual importance to the user (Lemer, 1998). The deprival cost highlights importance to the user and specifies how much it would cost to continue without a particular asset (Vanier, 2001). Finally, market value is the amount an asset could be sold for on the open market.

Building Life-Cycle Cost software is available for calculating asset worth values; however, studies show that practitioners rarely use it (Vanier, 2001). Rather, most organizations have their own set of calculations or rely on the experience of their experts. The Air Force utilizes the PRV approach. Understanding the basic components of identifying assets and determining their value builds the foundation for the remaining facility AM steps.

3. What is the deferred maintenance?

Once an asset inventory is built and costs are calculated, the focus shifts towards maintenance. More specifically, it is important to determine how much planned maintenance has been deferred to future years. This maintenance deference creates a snowball effect that generates significantly higher maintenance, repair, or replacement costs in the following years (Vanier, 2001). One study shows that only about 17% of asset failures are life-cycle based, whereas 83% of the failures are based on non-age related factors (Neelamkavil, 2009). The high amount of non-age related failures can easily originate from maintenance deferral, which places organizations in a reactionary maintenance mode. Vanier (2001) identifies that a Facility Condition Index (FCI) calculation, shown in Equation 1, is one method of identifying the amount of deferred maintenance for an asset. The FCI indicates a problem if the sum of the deferred maintenance (i.e., deficiencies) divided by the PRV is 0.15 or higher (Vanier, 2001).

$$FCI = \frac{\Sigma Deficiencies}{PRV} \quad (1)$$

4. What is the condition?

The next step is extremely important yet potentially difficult and time consuming to accomplish. Knowing the condition of an asset helps facility maintainers avoid outages, mitigate risks, reduce the probability of failure, predict future requirements, and enhance sustainability (NAMS & IPWEA, 2011). This process can be overwhelming to organizations with large asset portfolios; therefore, a condition prioritization scheme is often needed. NAMS & IPWEA (2011) provide some criteria to determine which assets to assess first: age, criticality, estimated remaining service life, presence of environmental conditions that could accelerate deterioration, and whether maintenance could even prevent failure.

Once a prioritized list of facilities is built, an organization can begin to collect the data that will help determine each facility's condition. FCI calculations are probably the most common method of determining condition in that no software is required (Vanier, 2001; Fagan & Kirkwood, 1997). As seen in Equation 1, the only requirements are a list of projects that will correct any observed deficiencies and the facility PRV. The FCI provides a quick estimate of the asset's condition; however, as stated in Chapter I, FCI calculations can lack credibility across the DoD. In other words, it is possible to skew the FCI calculation through poor condition assessments and project planning or by not understanding the facility's maintenance needs.

IT programs have been developed to provide facility managers with more accurate facility condition calculations (Vanier, 2001; Brandt & Rasmussen, 2002). For example, BUILDER™ utilizes component condition assessments as well as basic component age to calculate a condition (Grussing & Marrano, 2007). In response to guidance, the Air Force is currently completing Sustainable Infrastructure Assessments to gather condition data on critical facility components for inclusion into BUILDER™.

5. What is the remaining service life?

This step builds directly off the component conditions previously calculated. Vanier (2001) provides some service life prediction techniques but states that a considerable amount of data is required. Thus, IT systems such as a CMMS are valuable tools that can provide useful service life calculations. In fact, BUILDER™ calculates individual component service lives, which combine for an overall facility service life (Grussing, 2012). Service life is also shown in component condition curves produced by BUILDER™ as previously shown in Figure 4.

6. What do you fix first?

This step is best answered once the previous five steps are fully addressed (Vanier, 2001). This step should also include risk-based decisions on social (e.g., safety and health, service loss, or image), environmental, or economic criteria (NAMS & IPWEA, 2011). This allows facility managers to prioritize similar component needs under a constrained budget climate. Asset prioritizing may also reveal data gaps existing within the previous five steps (Vanier, 2001). For example, an organization might accurately record asset worth on nearly every facility but only thoroughly calculate 50% of the overall condition, thus making it difficult to prioritize work. Various IT tools, to include BUILDER™, can provide project lists once the appropriate data are gathered.

Facility AM Summary

Overall, the six questions above are essential for quality AM-focused decision-making. More importantly, it transitions organizations from costly reactive maintenance towards a proactive maintenance program. "When reliable data and effective decision-support tools are in place, the costs for maintenance, repair, and renewal will be reduced and the services will be timely, with less disruptions" (Vanier, 2001:13). Likewise, IT systems are vital to any facility AM program. NAMS & IPWEA (2011) highlight some key attributes for facility AM IT: modular with open architecture for future module upgrades, able to operate on common hardware systems and across industry standard databases (Oracle for example), interface with additional corporate systems, enable flexible report writing, and accept external/remote data. IT-powered AM programs can provide the means of managing facility programs in fiscally constrained environments.

CMMS Incorporation

Today, procedures in many organizations, both private and public, are shifting to a proactive mode of maintenance activities. To make this reactive-to-proactive change occur, an organization must first begin to manage the massive amounts of data that facilities produce (Labib, 2004). While many types of CMMS exist on the market, managers must focus time upfront, set goals, and determine which features are required. These new CMMS can provide the means to manage large amounts of data as well as capabilities that include (Crain, 2003; Bradshaw, 2004; Atere-Roberts & Bash, 2002; Labib, 2004; Huo, Zhang, Wang, & Yan, 2005):

- Manages component information
- Manages resources & labor
- Analyze historical records for condition modeling
- Develop & prioritize work plans

- Facilitate communication between departments
- Provide real time support for decision-making

BUILDER™ meets some but not all of the above CMMS capabilities. As previously mentioned, BUILDER™ relies on facility inspections to develop individual component conditions which combine together for the overall building condition index (BCI). Each facility contains a large variety of component types, which follow a basic condition decay curve as illustrated in Figure 8. The curve is based on the Weibull cumulative probability distribution as shown in Equation 2.

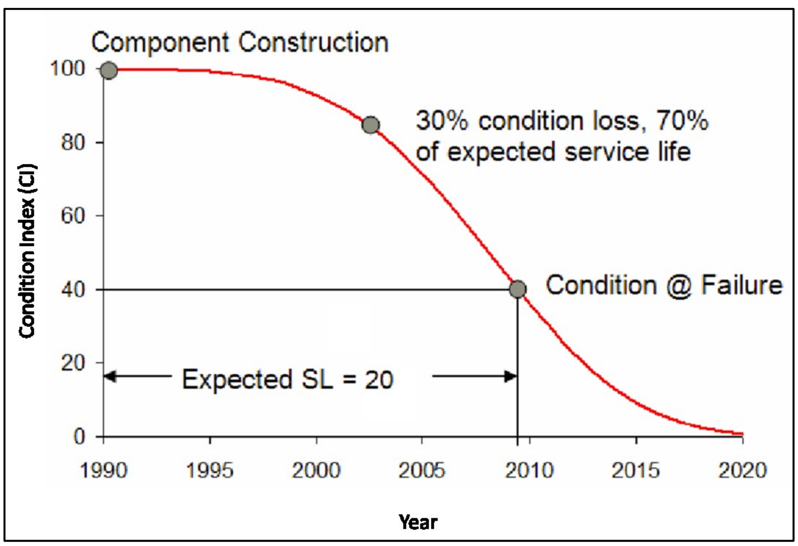


Figure 8. Component Decay Curve (Grussing, 2012)

$$C(t) = a \times e^{-(t/\beta)^{\alpha}} \quad (2)$$

where $C(t)$ is the CI at some point in time, t is the time in years, e is the exponential constant, a is the parameter for the initial steady state CI, β is the parameter for the service life adjustment factor, and α is the parameter for the accelerated deterioration factor. Grussing (2012) explains that the equation produces a condition index (CI) between 0-100 and that a CI of 40 is typically considered the component failure limit.

Additionally, as seen in Figure 8, the condition is relatively stable but then begins to decrease over time. Grussing and Marrano (2007) identify that a CI rating of 75-85 is considered the economic repair sweet spot where required repairs allow for the greatest cost effective method to extend component life-cycles. For any given component, the longer that a repair is deferred to a future time, the more costly the repair becomes. As the CI decreases, the repair costs increase exponentially until the component fails at a CI of about 40 as shown in Figures 8 and 9 (Grussing & Marrano, 2007). In other words, if a decision-maker waits too long to act, it will become more beneficial to replace the component instead of repairing it.

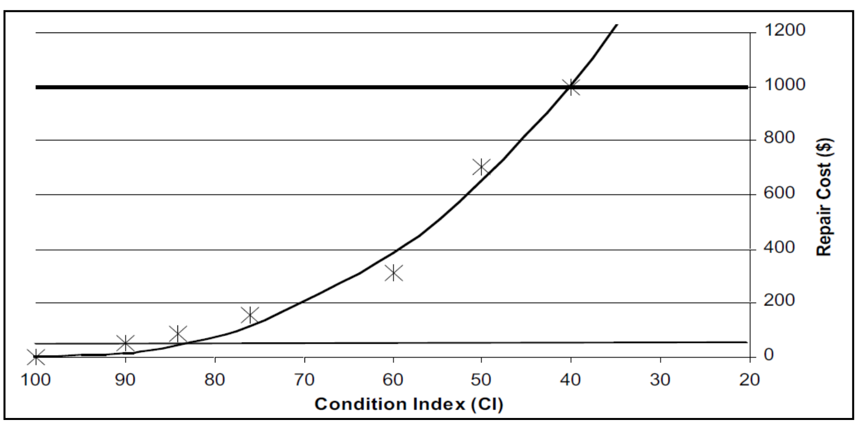


Figure 9. Unit Repair Cost Trend (Grussing & Marrano, 2007)

Instances will occur, however, when a component has progressed beyond the maintenance sweet spot, thus requiring a decision whether to repair or replace the component. Replacement costs in BUILDER™ are based on a default cost book adjusted for inflation and location (U.S. Army ERDC-CERL, 2007). For example, a repair that will bring the component up to a CI of 95 is calculated in BUILDER™ based on factors shown in Equation 3 (Grussing & Marrano, 2007).

$$C_{repair} = C_{replace} \times \left(\frac{100 - CI}{100 - CI_{term}} \right)^{N} \qquad (3)$$

where C_{repair} is the repair cost in \$, $C_{replace}$ is the replacement cost in \$, CI is the current CI, CI_{term} is the failure CI (40), and N is the cost escalation factor. To determine whether to repair or replace a component, Grussing and Marrano (2007) provide a Savings-to-Investment Ratio (SIR) calculation as shown in Equation 4.

$$SIR = \frac{S_t / (1+i)^t}{I_r / (1+i)^r} \qquad (4)$$

where S_t is the savings in \$ at some point in time (amortized replace cost × added service life), I_r is the investment cost in \$ at some point in time, t is the year that savings are realized, r is the year that repair/replacement is performed, and i is the discount rate (5%). Figure 10 emphasizes the decision to repair or replace by illustrating the opportune time to invest in a repair (e.g., when the CI is above 60 and optimally at 80).

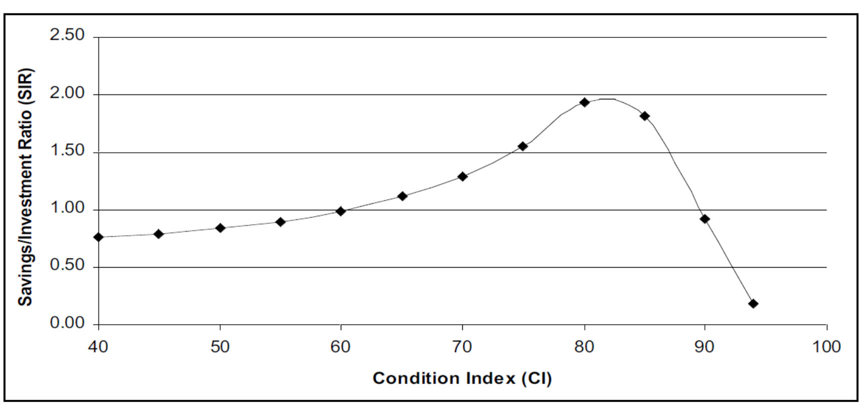


Figure 10. Optimal Repair CI for a Metal Window (Grussing & Marrano, 2007)

BUILDER™ utilizes each of these equations to determine the best alternative for each component requiring attention. A work plan can be created which provides every project that is expected for a given facility. Within the work plan, technicians can open an individual work item to compare repair and replacement values. Figure 11 illustrates a typical work item graph produced by BUILDER™. The graph illustrates four scenarios: perform a repair, replace the component, perform a stopgap repair, and do nothing. This depiction mainly serves to show the different service life outcomes for each decision.

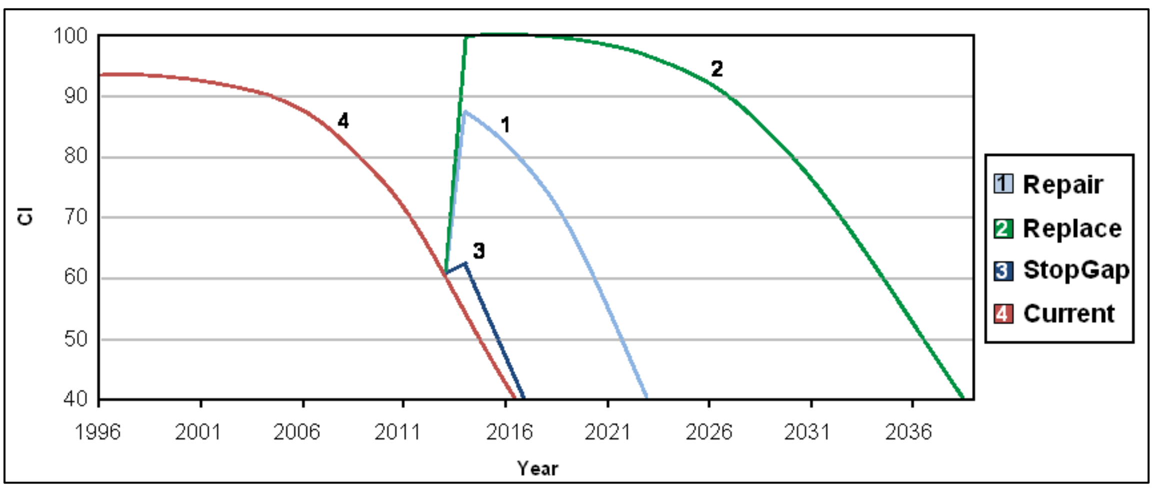
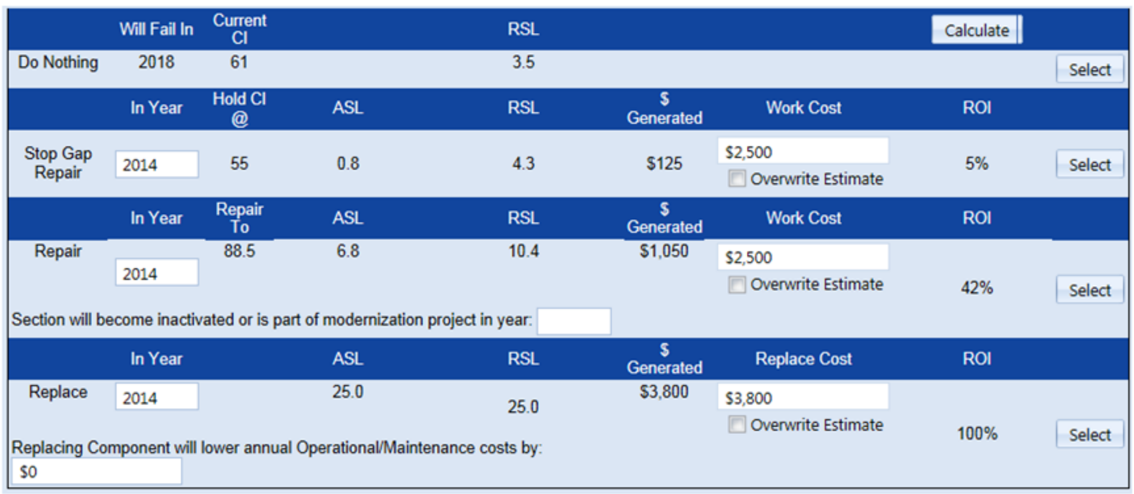


Figure 11. BUILDER™ Work Item Decision Graph

Accompanying the BUILDER™ graph is a breakdown of the four options as shown in Figure 12. If nothing is accomplished, the component will fail in 3.5 years. The stopgap represents a small band-aid fix and delays the failure to 4.3 years. The replacement calculation identifies that 25 years are added to the service life at a cost of $3,800. The section titled *$ Generated* signifies how much value comes from the respective decision. For a replacement, the full value of the replacement cost is generated as value. In the repair situation, 6 years would be added to the service life at a cost of $2,500. The value generated from the repair is calculated to be $1,050. The ROI calculation is found by dividing the *$ generated* by the *work cost*, and as seen here, it is more beneficial to replace the component. A manager can also manually edit some of the decision criteria such as additional energy or maintenance savings from a replacement, which will increase the replacement ROI for that component.



ASL = Actual Service Life, RSL = Remaining Service Life

Figure 12. BUILDER™ Work Item Decision Matrix

BUILDER™ is a powerful tool that tracks both facility real property and data on the many components belonging to each facility. Basic deterioration curves are immediately available once all the inventory data are added; however, continual facility inspections are required. These inspections are crucial so that BUILDER™ can update the condition curves appropriately. With up-to-date data, facility managers are able to generate a list of work items for each facility and create future planning scenarios based on various budget outcomes. Additionally, project lists are customizable for each organization. Individual standards, policies, and prioritization schemes can be set up so that the project list reflects the organization's priorities such as criticality, condition, age, and work type (U.S. Army ERDC-CERL, 2007). BUILDER^{TM} provides the means to help decision-makers transition their programs from reactive to proactive maintenance; however, to make the transition effective, managers should employ organizational change management techniques.

Organizational Change Management

Many organizations will attempt some sort of course correction or change throughout their existence. The initiative to implement change varies from case to case but can include responding to budget cuts, increasing profit, evolving with new technology, or surpassing competition. Interestingly though, based on a global survey conducted by two McKinsey consultants, only approximately one-third of the organizations that went through a change effort were actually successful according to their leaders (Meany & Pung, 2008). Some of the commonly admitted causes for the lack of success include failure to change the organizational culture and infrastructure, lack of integrations, lack of commitment of senior management, and lack of leadership (Arora & Kumar, 2000). As such, experts have developed various criteria and models to help managers successfully transform their organization (Lewin, 1947; Armenakis, Harris, & Mossholder, 1993; Harrison & Pratt, 1993; Kotter, 1995; George & Jones, 2001; Fernandez & Rainey, 2006).

One of the early concepts in organizational change management builds a three-step process: (1) unfreeze the organization by breaking a habit that the manager intends to change, (2) move the organization norm to the new standard, and (3) re-freeze the organization in this new habit (Lewin, 1947). While this process may be valid for a single undertaking with rather simple complexity, organizations often find themselves in an environment of multiple change efforts and in a period where overall change is accelerating (Kotter, 2008). This complexity requires management to focus additional attention on certain change criteria to achieve a desired outcome.

Change Behavior

When looking at a change implementation, the process typically follows a basic curve that gives insight into potentially troubling spots. Beaudan (2006) describes the implementation curve as having three basic components: launch phase, mid-course phase, and completion phase as shown in Figure 13. One of the first obstacles is the point where resistance to change begins, whether from an external source or the employees (or change recipients) themselves. This resistance causes the implementation progression to shallow out to a potential stall point, which in turn begins to cause fatigue throughout the organization (Beaudan, 2006). This stall point is a pivotal spot for management focus; otherwise, the chance for failure significantly increases.

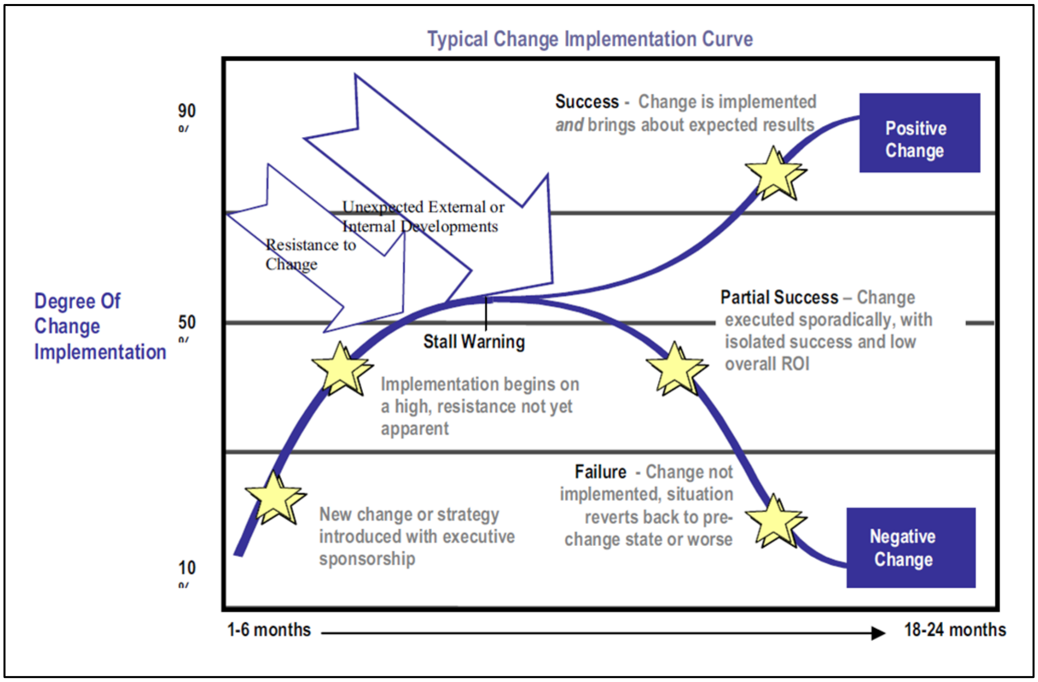


Figure 13. Typical Change Implementation Curve (Beaudan, 2006)

Research by Fonnesbeck (2003) provides similar implementation (labeled integration) curves through a systems dynamics approach. Figure 14 illustrates the interrelated behaviors with the organization's operating capability or OC, potential adopters, adopters, and integration. While the OC does not specifically pertain to this research topic, the other three are important to understand. As change progresses, the number of potential adopters decreases as they are converted to adopters. As this conversion takes place, integration begins to gain momentum. In other words, the only way to achieve integration is to convince the change recipients to support the change effort.

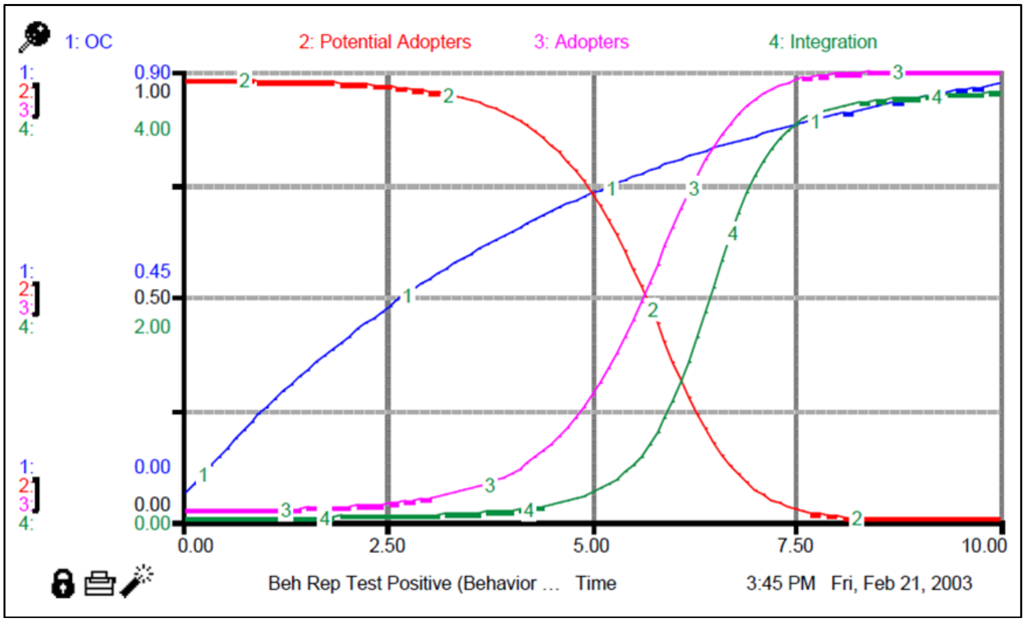


Figure 14. Ideal Implementation Curve (Fonnesbeck, 2003)

Figures 13 and 14 both depict basic change implementation expectations and identify those moments when management needs to focus attention to maintain positive progression. However, before a manager fixates on implementing change, they should first prepare and lay the groundwork that will strengthen the change effort. Although this research effort follows the institutionalization change model developed by Armenakis and Harris (2009), Van de Ven and Sun (2011) provide an argument that managers should develop a repertoire of models in case course corrections are needed along the change process. Understanding the various model options may help managers modify strategies along the way, yet this is not within the scope of this research. Figure 15 demonstrates the model developed by Armenakis and Harris (2009) which has been divided into five sections (for description clarity) that are discussed in the following sections of this chapter.

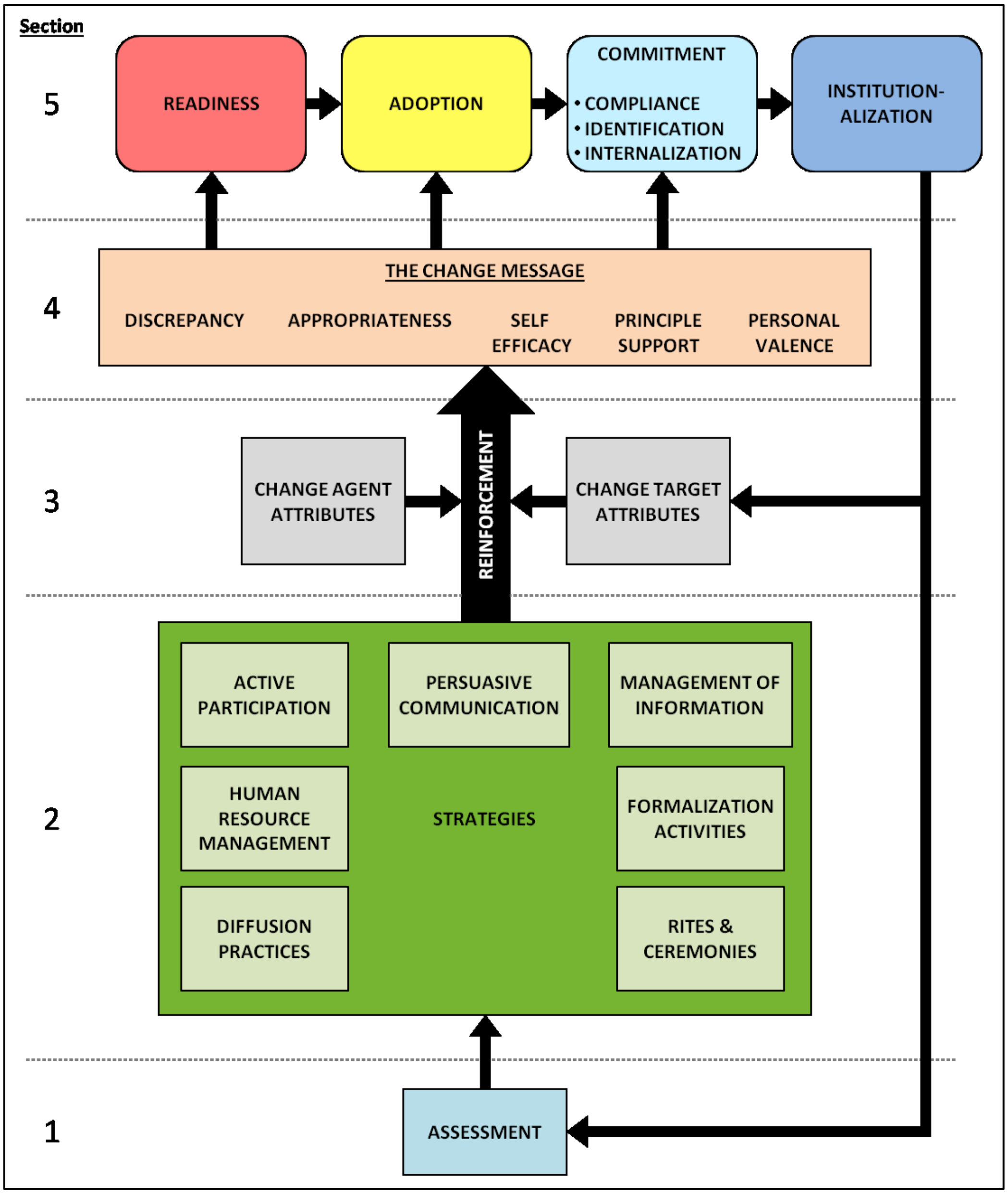


Figure 15. The Institutionalizing Change Model
(Adapted from Armenakis & Harris, 2009)

Change Model Section 1: Assessment

First, a manager must assess the current state, or readiness, of their organization. An initial "assessment enables leaders to identify gaps that may exist between their own expectations about the change initiative and those of other members" (Holt, Armenakis, Feild, & Harris, 2007:233). This step provides valuable initial information that will help managers during the development of the change initiative and should become a continual process to gauge successfulness of the effort. Even if the change effort is somewhat of a failure, a post assessment provides valuable insight on ways to revise the change process and proceed to implement the change (Armenakis & Harris, 2009).

Utilizing surveys, observations, and/or interviews, managers gain insight into the change process, content, and context, as well as change recipient attributes (Holt et al., 2007). The change process, or section five in Figure 15, is discussed below. Change content refers to the actual situation that the manager is attempting to implement. After the initial assessment, it could be possible that some areas of the change are just not ready to implement at the time. Change context is important in that it reveals the state of the organizational environment and provides an indication of employee loyalty and commitment towards the organization (Armenakis et al., 1993). Finally, information on employee attributes can greatly influence a manager's direction of a change initiative.

Focusing on the latter benefit from an initial assessment, change recipient attributes, it is crucial for an organization to be cognizant of their employee's beliefs and attitudes in this early stage because without change recipient buy-in, managers may find it incredibly difficult to move forward. When looking at change recipients, some variability will exist in factors such as personal traits, coping styles, needs, and demographics among employees (Oreg et al., 2011). A change resistance attitude that can affect change progress is employee cynicism. Research has shown that numerous failed change attempts, mergers, and new managers implementing instant change will create an environment where employees tend to meet future change with immediate skepticism (Reichers, Wanous, & Austin, 1997; Wanous, Reichers, & Austin, 2000; Bordia, Restubog, Jimmieson, & Irmer, 2011).

Change Model Section 2: Strategies

The strategies section builds a toolbox of methods that will strengthen the overall change message (Armenakis & Harris, 2009). Armenakis and Harris (2009) specifically highlight the first three strategies in their research: active participation, persuasive communication, and management of internal/external information. These three are likely to be required for any change initiative. Additional strategies are also identified to shape the change message: human resource management practices, formalization activities, diffusion practices, and rites and ceremonies (Armenakis & Harris, 2009).

The first strategy, active participation, includes three forms: enactive mastery (i.e., learn from doing), vicarious learning (i.e., observe others), and participation in decision-making (Armenakis & Harris, 2002). This involvement empowers change recipients to feel like they are a part of the change initiative. The second strategy, persuasive communication, addresses the format used to convey the change message. Communication techniques include speeches, memos, and reports (Armenakis & Harris, 2002). This is obviously an important strategy to develop because it is the only way that change recipients can understand management's vision and expectations. Managing information from internal and external sources is the third and equally important strategy. This can also tie into the first strategy by providing information about other organizations that have accomplished similar change (Armenakis & Harris, 2002). Not only does additional information keep employees updated with the change progress, it can also help eliminate rumors or anti-change comments among change recipients. While it is important to utilize these strategies, each organization and change process will differ, thus influencing how the change message is communicated.

Change Model Section 3: Attributes

With change strategies directly influencing the change message, attributes of the change as well, as the change agent, can greatly influence the effectiveness of the strategies. Along with the focus on strategies and the change message, a change agent must understand their own beliefs and management styles. One overriding characteristic to be understood is the degree of transactional or transformational leadership style in a change agent. A transactional leader sets objectives and goals and utilizes punishments or rewards to promote employee conformity (Transactional Leadership, n.d.). Transactional leaders are also known as “the dealmaker who can acquire huge companies, put them together, take out tens of thousands of jobs, and then move on” (George, 2006:69). A transformational leader, on the other hand, specifies the need for change, provides a vision to inspire, and implements the change with employee commitment (Transformational Leadership, n.d.). George (2006) further describes transformational leaders as ones who “are organization builders, willing to make investments required to build a sustainable organization that will create lasting value for all its stakeholders” (George, 2006:71). Since stakeholders also include the employees themselves, becoming a transformational leader can have a positive influence on the change message.

Furthermore, depending on the complexity of change and organizational size, a manager may appoint lower-level change agents to help support the effort. These mid-level change agents act “as intermediaries between top management and the front line [change recipients]” (Lüscher & Lewis, 2008:221), and it is this constant interaction with the front line that is important. Mid-level change agents should also embody certain characteristics such as personal skills, knowledge/experience in the company, knowledge/experience with quality, and the right attitude to promote change (Hutton, 1994). By choosing appropriate mid-level change agents, management should notice a more successful implementation of a change (Lam & Schaubroeck, 2000). Ultimately, a top-level manager must not only understand their own abilities and leadership style, but they must also involve mid-level change agents that embody similar characteristics. Utilizing a multi-faceted change agent team promotes higher levels of perceived organizational support, which in turn can increase employee performance and change message acceptance (Lynch, Eisenberger, & Armeli, 1999).

Change Model Section 4: Change Message

The change message is the primary element in the change model. While the other elements described above are important, a poorly developed change message can cause detrimental effects on the change implementation. The framework of a change message consists of five components (Armenakis et al., 1993; Armenakis & Harris, 2002; Armenakis & Harris, 2009): discrepancy, appropriateness, self-efficacy, principal support, and personal valence. It is important for change agents to address each component to compose an influential change message.

One of the first steps in any change process should involve identification of the discrepancy, or gap, between the organization’s status quo and desired end-state (Armenakis, Bernerth, Pitts, & Walker, 2007). Presenting this discrepancy to the organization is critical because change recipients "must believe that a need for change exists" (Armenakis et al., 2007:485). Otherwise, employees will perceive the change event as unnecessary and resist its implementation. A clear identification of the problem provides the foundation for the remaining elements of the change message.

Next, the appropriateness element presents details on how the proposed change fits the needs of the organization's new path. While it may be easy for employees to understand the discrepancy, it is possible that they will disagree with the proposed change (Armenakis & Harris, 2002). As such, it is important to highlight the many specific benefits of the proposed change. Armenakis et al. (2007) identify that when managers select initiatives, or fads, based on another organization's success, change recipient buy-in is difficult to obtain. When one organization has shown success in a change initiative, a manager may find it attractive to follow; however, they must first adequately assess (section one of the model) their own organization as compared to the other. For example, organizations in Japan may find it easy and advantageous to implement lean procedures, yet the organizational structure in the U.S. may not easily allow this change to occur.

Self-efficacy is the confidence in the organization's ability to succeed in the change initiative and an employee will only be motivated to accomplish a task that they feel they are capable of performing (Armenakis & Harris, 2002). This part of the change message conveys that the change initiative is achievable. The pre-change assessment may aid in providing information on how change recipients feel about their current capabilities. For example, one may find that the organization already feels stressed on manpower, and the change may appear to require more manpower to perform. If this is the case, it is possible that additional resources will be required, at least during the change process.

Principal support is the component that identifies how management will support the organization during the change effort. This support involves resources and continued commitment from the change agent as well as mid-level change agents (Armenakis & Harris, 2002). Armenakis et al. (2007) identify that support begins from the explanation of the discrepancy and that an alignment or misalignment of words to deeds, or "walking the talk," can have an effect on change recipient behavior.

Finally, personal valence is simply "the belief that the change is beneficial to the change recipient" (Armenakis & Harris, 2009:129). While it is understandable how the organization will benefit from the change, employees like to know how the change will have a positive effect on them directly. Valence can also be either extrinsic or intrinsic in nature. Extrinsic valence involves rewards or benefits to the employee, and intrinsic valence, though slightly more subjective, may provide better autonomy for decision-making at the employee level (Armenakis et al., 2007).

Change Model Section 5: Change Process

The final section illustrates the overall change process within an organization. This process stems from Lewin's (1947) original three-phase model now labeled readiness, adoption, and institutionalization (Armenakis & Harris, 2002). More recently, Armenakis and Harris (2009) also added commitment to this process. This fifth section is the real-time occurrence of the change event. While it is ideal to accomplish the previous four sections pre-change, it is possible that modification to these areas is necessary during the change event. Typically, when change is not proceeding as planned, change agents tend to act by correcting people or processes; however, agents should instead reflect on and revise the change message and/or strategies (Van de Ven & Sun, 2011).

The first phase of the change process, readiness, is the time when employees prepare for the change (Armenakis & Harris, 2002). At this point, the change message is a critical factor for influencing change recipients. Referring back to Figure 14, it can take time to convert potential adopters to adopters, as shown in the S-curve behavior. The sooner the organizational readiness is established, the sooner the change progress can shift to the steeper part of the S-curve. This process transitions the organization to the second phase, adoption. Although this appears to be a point of strong positive momentum, it is also considered as an experimental period where adopters can shift back to potential adopters or even resistors (Armenakis & Harris, 2002). To maintain positive momentum, change agents must continue communicating the change message. One particular important component of the message at this stage is principle support, which also aligns with the third phase in which commitment comes from both the change agent(s) and recipients. Continual communication of the change message will ultimately help the organization reach the fourth phase, institutionalization.

Overall, implementing change is a hands-on process, and managers cannot embark on a change and then focus all their attention elsewhere. Time and attention should be directed to the first four sections of the change model developed by Armenakis and Harris (2009). Next, continued communication of change message is necessary to advance the change process through the four phases. Finally, as depicted in Figure 15, the overall change process is cyclical, and it is important to continually assess the organization and address any setbacks by revising change strategies or the message itself to sustain the change inertia (Armenakis & Harris, 2009).

Summary

This literature review provided an overview on research that illustrates a need to employ facility AM concepts to set the foundation for a successful proactive facility maintenance program. CMMS programs, specifically BUILDER™ in this research effort, help decision-makers transition their facility programs from reactive to proactive maintenance. Organizational change management techniques are also presented to increase BUILDER™ implementation effectiveness in the Air Force. The following chapter presents the Delphi study technique, which was utilized to strengthen the change message and overall BUILDER™ implementation plan.

III. Methodology

This chapter presents the methodology used to elicit expert knowledge on Air Force facility maintenance programs. The Delphi study technique is introduced along with the decision criteria used in the research effort. Subject matter expert (SME) opinions were collected through three rounds of questionnaires interspersed with feedback from the researchers. The analyzed data will be primarily used to reinforce the BUILDER™ implementation change message that is presented in Chapter V.

Delphi Study

The Delphi study technique was developed by the RAND Corporation during the 1950s in response to an Air Force sponsored project. The project involved the application of expert opinion to determine optimal United States target systems that a Soviet strategic planner would choose (Rowe & Wright, 1999). The objective of a Delphi study is "to obtain the most reliable consensus of opinion of a group of experts…through a series of intensive questionnaires interspersed with controlled opinion feedback" (Dalkey & Helmer, 1963:458). According to Rowe & Wright (1999), the Delphi process consists of four features: anonymity, iteration, controlled feedback, and statistical aggregation of group response. These features are summarized below.

1. Anonymity: Utilizing questionnaires allows SMEs to express their opinion without pressure from peers or reprisal from senior leaders. This allows individuals to focus directly on the issue.
2. Iteration: Questionnaires are distributed several times to allow SMEs to refine their opinion based on group thought progression. Iteration creates

a group think environment capturing a wide range of ideas and opinions that would typically be difficult to discuss face-to-face among peers.

3. Controlled Feedback: Feedback is provided between rounds to inform SMEs of the collective responses. This allows individuals to adjust their response if needed.

4. Statistical Aggregation of Responses: Arithmetic medians for each questionnaire item are provided to show how the group is either thinking alike or if some ideas differ vastly among the panel. This difference has the potential to stimulate further discussion and discovery of significant principals. (Skulmoski & Hartman, 2007)

A typical Delphi study utilizes three rounds of questionnaires as depicted in Figure 16 (Skulmoski & Hartman, 2007). The first round begins with an open-ended questionnaire based on literature and experience (Hsu & Sanford, 2007). Responses are analyzed and combined by the researcher. During subsequent rounds, aggregate responses are provided back to the panelists where they then have the option to modify their input and rate each response (Rowe & Wright, 2001; Hsu & Sanford, 2007). Finally, data results are generalized and documented for the research effort.

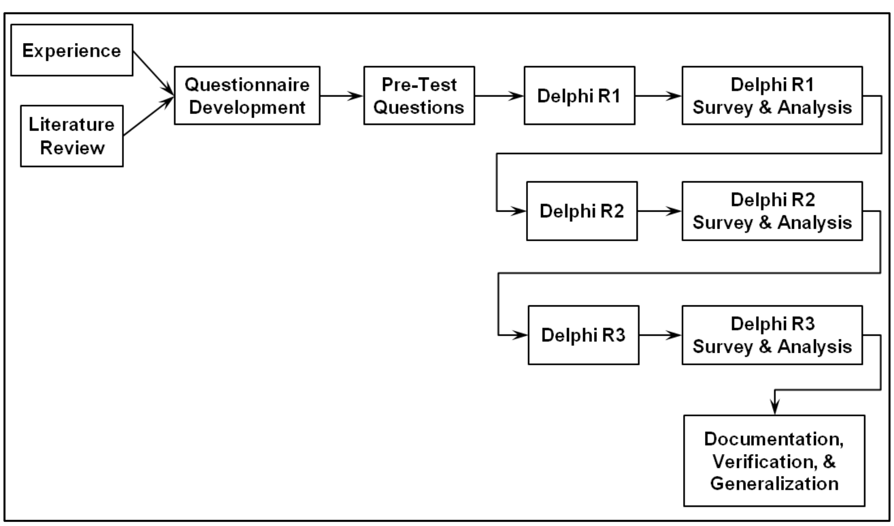


Figure 16. Typical Delphi Process
(Adapted from Skulmoski & Hartman, 2007)

The first step of the Delphi process involves the development of an open-ended questionnaire that is based on literature review and the researcher's experience (Skulmoski & Hartman, 2007). The initial questions in this research effort are based on facility AM principles and are intended to elicit responses that will form and enhance a change management strategy for implementing BUILDER™. Seven questions were divided into two categories on facility maintenance programs and Computerized Maintenance Management Systems (CMMS) for the round-one questionnaire, found at Appendix A.

The next step bridges the first and second Delphi rounds. The researcher analyzes the responses from the first round and performs qualitative coding to generate common themes (Skulmoski & Hartman, 2007). Qualitative coding involves segmenting the data and assigning a category name (e.g., IT system is outdated, inadequate resources, etc.) to meaningful segments (Johnson & Christensen, n.d.). Aggregated themes are then compiled for the second round questionnaire, which will allow panelists to rate each response based on two versions of a five-point Likert scale:

5-Strongly Agree → 1-Strongly Disagree
5-Very Important → 1-Unimportant

The Likert scale has shown to be easily understood by respondents and provides reliable results on the average attitude of the group for each topic (Linstone & Turoff, 2002; Likert, 1932). The Delphi round-two questionnaire, found at Appendix B, was developed and then delivered to the panelists who were instructed to rate each theme and provide additional comments as needed.

On receipt of the second round of replies, an analysis of the Likert scale responses was conducted to determine whether a consensus exists. Simple statistical methods are available to determine central tendencies (i.e., mean, median, and mode) and panel agreement (i.e., inter-quartile range and standard deviation) for each theme (Hsu & Sanford, 2007). Consensus can be indicated in various ways, two of which require that "80 percent of subjects' votes fall within two categories on a seven-point scale…[or] 70 percent of Delphi subjects need to rate three or higher on a four-point Likert-type scale and the median has to be at 3.25 or higher" (Hsu & Sanford, 2007:4). However, for this research effort, consensus is based on the arithmetic median and inter-quartile range (IQR) which contains the answers of the middle 50 percent of the respondents. When working with five-point Likert style questionnaires, the IQR is expected to be one or less to assume consensus (Scheibe, Skutsch, & Schofer, 2002).

A third Delphi round may be helpful if a consensus is not reached, or when the IQR is greater than one. The third-round questionnaire, found at Appendix C, provides panelists with the group's median response for each theme and allows them to re-rate those items that did not reach a consensus. The analysis for the third-round questionnaire is performed similar to the previous round's analysis where the new medians are calculated along with the new IQR. It is very possible that consensus may not be reached on every theme and subsequent rounds may only cause pressure for panelists to conform to the group's median response (Hsu & Sanford, 2007). Therefore, this research effort concluded after the third round of the Delphi process.

Delphi Panel Composition

Since a Delphi study is highly reliant on input from SMEs, it is crucial to choose appropriate panel experts. There are three types of panelists that can be considered for a Delphi study: stakeholders who could be affected by the research; experts with relevant knowledge on the subject area; and facilitators skillful in clarifying, organizing, synthesizing, and stimulating (Scheele, 2002). Additionally, panelists should have the capacity and willingness, as well as sufficient time, to participate in the study (Skulmoski & Hartman, 2007). While there is no standard for the number of experts included in a study, a majority of the studies involve 15-20 panelists (Ludwig, 1997). Skulmoski and Hartman (2007) present three trade-offs that may exist when choosing panelists: heterogeneous or homogeneous sample, decision quality or Delphi manageability, and internal or external verification. Each trade-off is dependent on the particular research effort and the researcher's experience. Large groups tend to increase the decision quality but can be difficult to manage in a Delphi approach and will most likely require a follow-up verification study (Skulmoski & Hartman, 2007). According to the literature above, 10-15 panelists were targeted for this research effort.

The research sponsor, the Air Force Civil Engineer Center, provided a general list of SMEs. These experts represent the following personnel from Civil Engineer Operations Flights: Senior Enlisted Section Chiefs, Operations Engineering Chiefs, Deputy Flight Chiefs, and Flight Commanders. This sample of SMEs represents five of the Major Commands across the Air Force: Air Combat Command, Air Mobility Command, Air Force Materiel Command, Air Education and Training Command, and

Air Force Space Command. An original list of 61 names was provided, of which 11 agreed to participate in the study.

Furthermore, because information from SMEs is considered as an interaction with human subjects, the Institutional Review Board (IRB) requires an assessment of the research process. The intent for this IRB review is to ensure that no harm will come to human subjects as a result of the research. This research has the potential of retribution because the subjects are government employees providing their opinions, whether positive of negative, on the facility maintenance process currently in practice. To minimize this potential or retribution, the handling of Personally Identifiable Information (PII) is strictly controlled by the researcher and faculty advisor. Furthermore, analyzed results were stripped of PII during the research and all PII were destroyed upon completion of this research effort. In light of these two factors, this research qualified for an IRB exempt status, which can be found at Appendix D.

Summary

This chapter provided the steps to collect qualitative data from SMEs to help enhance the implementation procedures for BUILDER™. The Delphi study technique was performed to gather expert opinions on current Air Force facility maintenance procedures, expectations of well performing maintenance programs, and CMMSs. Analysis and results to this methodology are discussed in the following chapter.

IV. Analysis and Results

This chapter presents the analysis and results from the Delphi study. As mentioned in earlier chapters, the Delphi study was used to gather opinions from Air Force Civil Engineer (CE) facility maintenance Subject Matter Experts (SMEs). The results from this Delphi study are intended to strengthen a change message used during the implementation of BUILDER^{TM}. The chapter structure follows the typical Delphi process: round-one questionnaire development, results and analysis from round-one, round-two questionnaire development, consensus analysis of round two, round-three questionnaire development, consensus analysis of round three, and final analysis of results. One limitation found during this study was that some of the panelists became task overloaded and could not complete the study. Additionally, the timeframe for the study occurred during the winter holiday season which seemed to affect participation.

Round One Questionnaire

The first round questionnaire addressed facility maintenance programs and Computerized Maintenance Management Systems (CMMS). The seven questions, shown in Table 1, were structured to add value to specific areas of the change process developed by Armenakis and Harris (2009) which were discussed in Chapter II. Discrepancy is one of the main focus elements in many of the questions from round-one. While a macro-level viewpoint of facility maintenance deficiencies exists in upper echelons of the CE career field, input from the workforce should add benefit to the change process. The next focus area correlates BUILDER^{TM} capabilities to the current IT system, Interim Work Information Management System (IWIMS). Personal valence also exists within one of the questions to attempt to link the use of BUILDER™ to individual benefits recognized by technicians. Finally, a question on metrics provides managers useful tools during the assessment process.

The literature provides guidance that questionnaire should be pre-tested by colleagues not part of the study to identify unclear items (Skulmoski & Hartman, 2007; Turoff, 2002). Therefore, the round-one questionnaire was pre-tested by Air Force graduate students in the CE career field to ensure that the questionnaire was clear and easy to take. Following the pre-test, the round-one questionnaire, found at Appendix A, was delivered to the panelists who were given two weeks to provide responses.

Table 1. Round 1 Question Correlation

	Question	Change Process Element
Facility Maintenance	How would you design an ideal facility maintenance program?	Discrepancy
	Please identify a few metrics (standard practice or customized) that you would use to gauge success.	Assessment
	How effective is the current facility maintenance program?	Discrepancy
	What is needed to strengthen the current facility maintenance program (i.e. transition to an ideal program from question 1)?	Appropriateness & Personal Valence
CMMS	How well does IWIMS meet your needs in managing a facility maintenance program?	Discrepancy
	Please identify a few IWIMS capabilities that you find valuable as well capabilities that are not useful or could be improved upon.	Discrepancy & Appropriateness
	What are a few key capabilities that you expect from a CMMS to properly manage your facility maintenance program?	Discrepancy

Round One Analysis

The first questionnaire was distributed shortly before the winter holiday season, and as mentioned above, a low participation rate occurred where only 5 of the 11 panelists responded. Additionally, one panelist requested to withdraw from the study, which reduced the target panel size to ten SMEs. While a 50% participation rate was less than anticipated, the responses provided were still adequate when compared to findings from the literature.

Responses were summarized and aggregated for each question. A total of 91 items were coded resulting in 56 generalized themes. The frequency of occurrences for each theme is shown in Table 2. The frequency provides a few observations each of the themes. High frequency themes seem to demonstrate a common opinion among the panelists, but the low frequency themes also provide a unique observation. On one hand, a particular theme might be unpopular or not that important, but on the other hand, it could be an important opinion that other panelists did not consider. These observations demonstrate one of the main purposes of a Delphi study.

Table 2. Aggregated Responses and Frequencies

1) Components of an ideal facility maintenance program

Theme	Frequency
Should be able to account for & prioritize resources (money, material, manpower)	5
Identify when maintenance should be performed	4
Enable investment plans (short/mid/long term)	5
Focuses on PM	3
PM should be focused on system performance not pre-determined frequencies	3
Enables prediction of effects & consequences of decisions	1
Identify maintenance that is above in-house scope	1
Centralized management, decentralized execution	1
PM should be based on standardized AF directive or manufacturer recommendations	1
IT systems that are easy for day-to-day use	1

Table 2. Aggregated Responses and Frequencies (cont).

2) Metrics to gauge a facility maintenance program

Theme	Frequency
Productivity index (emergency vs. routine vs. preventive)	3
Rate resources (man-hours, overtime, material, contract cost) vs. rate of PM (by facility age)	3
Downtime	2
Mean time between failure (MTBF)	2
System/component failure vs. life-cycle	2
Actual investment rate vs. planned	1
Cost ($ and/or man-hours) of second order effects (i.e. system failure affected a number of other components that rely on the system)	1
Budget performance (did spent money achieve desired objective)	1
Energy consumption	1

3) Effectiveness of the current facility maintenance program

	Theme	Frequency
Strengths	Can-do' attitude of technicians & engineers keep facilities operational with no mission failure	2
	CE transformation focuses on PM and overall organizational prioritization (AF/MAJCOM wide)	2
	RWP program focuses work on PM	1
Weaknesses	Resources are inadequate	5
	Current workload is overwhelming	3
	Wrong priorities are focused on (i.e. not on PM)	3
	Current IT systems are outdated	2
	Current IT systems don't communicate with each other effectively	1

4) What is needed to transition to a better facility maintenance program

Theme	Frequency
Additional resources (money, manpower, component tracking tools)	4
Targeted maintenance	3
Implement a modern IT system	2
Prioritize projects that are 'worst-first'	1
A way to communicate (w/ adequate data) the importance & importance of PM	1
Collect & manage Facility Condition Assessments	1

Table 2. Aggregated Responses and Frequencies (cont).

5) How does IWIMS meet current facility maintenance needs

	Theme	Frequency
Strengths	Good for labor & trend analysis	2
	Contains valuable information	1
	Enables CES to perform their mission	1
Weaknesses	Doesn't meet current needs	4
	Difficult to pull data	4
	A drain on resources	3
	Doesn't communicate to other IT systems efficiently	1
	Limited in the ability to manage a facility maintenance program	1

6) Capabilities of IWIMS

	Theme	Frequency
Strengths	Tracks historical data (material costs, labor, etc.)	3
	People know how to use it	3
	Provides good shop rate calculations	1
Weaknesses	Difficult to use	4
	Can't perform required tasks	3
	Doesn't communicate to other IT systems	2
	It's an internal system that doesn't communicate with sister services or higher commands	2
	Outdated	1

7) Capabilities expected in a CMMS

Theme	Frequency
Prompt for future maintenance work	4
Exports usable metrics/reports to advocate for funds	4
Computes component conditions	3
Prioritizes work	2
Tracks material	2
Tracks work order requests (332s)	2
Compatible with other IT systems	2
Universal across the services	1
Easy to manage and input data	1
Tracks real property & equipment inventory	1

The high frequency response data for current facility maintenance programs suggest that resource levels seem to be inadequate, thus creating an overwhelming workload that does not focus enough on preventive maintenance (PM) priorities. According to these results, an efficient program should focus on PM, enabling proper investment planning and identification of upcoming maintenance requirements. Specific to CMMS programs, the expectation is that the program has the capability to prompt managers of upcoming work and provide usable metrics or reports to help managers advocate for maintenance funds. Furthermore, respondents generally agreed that the current IWIMS program, is outdated, difficult to use, and does not perform the tasks required for efficient facility maintenance. Importance of other, low frequency themes, is explored in subsequent questionnaire results.

Round Two Questionnaire

The second round allowed panelists to review and compare their first round answers to the aggregated themes from the group. One unique aspect of this round is that it creates a collaborative atmosphere, which allows panelists to specifically review and evaluate the low frequency themes from round one. Panelists were asked to rate their position on each theme using the following two rating systems that are based on the five-point Likert scale. Themes grouped by strengths and weaknesses required a different rating scale than the other general themes.

5-Strongly Agree → 1-Strongly Disagree
5-Very Important → 1-Unimportant

The second questionnaire was modified slightly from the first round results, which were shown in Table 2. First, sections five and six contain similar responses; therefore, they were combined into a single grouped theme on current CMMS strengths and weaknesses. The next modification was the deletion of the metrics section. The responses seemed to differ depending on a SME's experience with specific metrics that may not be commonly used or understood by other panelists. Furthermore, standard metrics and operating procedures are currently in place in the CE career field; therefore, this question was beyond the scope of this research effort. Five categories were thus presented in the second round questionnaire with a total of 46 themes, which can be found at Appendix B.

Similar to the first round, the round-two questionnaire was pre-tested by Air Force graduate students in the CE career field who did not participate in the round-one pre-test. Again, the pre-test should ensure that the questionnaire was clear and easy to take. Additionally, research explains that response rates drop when questionnaires become too long (Gräf, 2000). While not every theme may have an influence on the change message, it was still important to include each response to remove researcher bias and allow discussion on low frequency comments. Bosnjak and Batinic (2000) specify that for a questionnaire that takes 15 minutes to complete, approximately 50% of participants are willing to take it; whereas, up to 78% are willing to take a questionnaire that only takes 10 minutes. Therefore, to help counter the issue with the length of the questionnaire, focus was placed to ensure that it was simple, easy to understand, and could be accomplished in 10 to 15 minutes.

Round Two Consensus Analysis

Typically, the response rates decrease in subsequent Delphi rounds (Jillson, 2002); therefore, the second round questionnaire was delivered to the entire ten-member panel with the intent to gain additional feedback from those that did not participate in round one. Seven panelists responded resulting in a 70% response rate. As previously mentioned in Chapter III, simple statistical methods are available to determine central tendencies (mean, median, and mode) and panel agreement (inter-quartile range and standard deviation) for each theme (Hsu & Sanford, 2007). For this research effort, consensus was based on the arithmetic median and inter-quartile range (IQR), which contains the answers of the middle 50 percent of the respondents. When working with five-point Likert style questionnaires, the IQR is expected to be one or less to assume consensus (Scheibe et al., 2002).

Of the 25 themes under the facility maintenance program category, only eight did not reach a consensus. Table 3 identifies the group's median response and IQR for each facility maintenance theme. As seen in the table, the eight themes with an IQR above one are dispersed throughout each facility maintenance category. Next, Table 4 identifies the results for each CMMS theme. Of the 21 themes under the CMMS category, only four did not reach a consensus. In this situation, the four themes with an IQR above one are all in the Current CMMS category. No issues stand out among any of the responses that arrived at a consensus in either table. Since 12 items did not reach a consensus, a third Delphi round was undertaken to explore this further.

Table 3. Round Two Responses – Facility Maintenance Programs

Current Program: The following items were identified as strengths and weaknesses of current facility maintenance programs

	Theme	Rating *(agreement)*	IQR
Strengths	Technician & engineer 'Can-do' attitudes keep facilities operational with no mission failure	4	1
	CE transformation focuses on PM and overall organizational prioritization (AF/MAJCOM wide)	5	1
	RWP program focuses work on PM	**4**	**2**
Weaknesses	**Resources (people/time/money) are inadequate**	**4**	**1.5**
	Current workload is overwhelming	**4**	**1.5**
	Focus is placed on the wrong priorities (i.e. not on PM)	**3**	**1.5**
	Current IT systems are outdated	5	0
	Current IT systems do not effectively communicate with each other	5	0.5

Ideal Program: Aspects of an efficient facility maintenance program identified in round 1.

Theme	Rating *(importance)*	IQR
Should be able to account for & prioritize resources (money, material, & manpower)	5	0
Identifies when maintenance should be performed	5	1
Enables the development of an investment plan for maintenance requirements that are short, mid, & long term	5	1
Focuses on PM	4	0.5
PM should focus on system/component performance not pre-determined frequencies (i.e. manufacturer recommendations)	4	1
Enables managers to predict the consequences of their decisions	4	1
Identifies maintenance that is above in-house scope	**4**	**2**
Centralized management, decentralized execution	3	1
PM should be based on standardized AF directives or manufacturer recommendations	4	1
Uses IT systems that are easy for day-to-day use	5	0

Program Transition: The following items were identified in round 1 as needed to transition current facility maintenance programs towards more efficient programs.

Theme	Rating *(importance)*	IQR
Additional resources (money, manpower, component tracking tools)	4	1
Focus on intentional & targeted maintenance (i.e. pre-planned & based on life-cycle conditions)	4	1
Implement a modern IT system	**5**	**1.5**
Prioritize projects that are 'worst-first'	**4**	**1.5**
Implement a system provides data to help communicate the impact & importance of PM	4	1
Need to collect & manage Facility Condition Assessments	**4**	**1.5**

Table 4. Round Two Responses – CMMS

Current CMMS: IWIMS was identified in round 1 to have the following strengths and weaknesses when it comes to its ability to support facility maintenance programs.

	Theme	Rating *(agreement)*	IQR
Strengths	**Tracks historical trend data (material costs, labor, etc.)**	**4**	**1.5**
	People are familiar with it and know how to use it	3	0.5
	Contains valuable information	**3**	**1.5**
	Enables CES to perform their mission	4	0.5
	Provides good shop rate calculations	**3**	**1.5**
Weaknesses	Difficult to use	4	1
	Can't perform required tasks / doesn't meet current needs	5	0.5
	A drain on resources to operate / data mine	**5**	**1.5**
	Doesn't efficiently communicate to other IT systems	5	0
	It's an internal system that doesn't communicate with sister services or higher commands	5	0
	Outdated	5	0

Ideal CMMS: The follow items were identified as expected capabilities of a CMMS.

Theme	Rating *(importance)*	IQR
Identifies future maintenance work requirements	5	0
Exports usable metrics/reports to advocate for funds	5	0
Computes current & future component conditions	4	1
Prioritizes work	5	1
Tracks material	5	0.5
Tracks work order requests (332s) through the whole cycle	5	0.5
Compatible with other IT systems	5	0.5
Universal across the services	4	1
Easy to manage and input data	5	1
Tracks real property & equipment inventory	5	1

Round Three Questionnaire

The third round allows panelists another chance to review and compare their responses to the aggregated data. Panelists were only presented with the items that did not reach consensus from round two. One item in the fourth category, *contains valuable* *information*, was removed for the third round questionnaire because it is closely related to the item on *historical trend data* in the same category. Additionally, clarification was added to each theme. Of the remaining 11 items, the group's arithmetic median rating and IQR from round two was presented to the panelists. Refer to Appendix C for the third questionnaire. The overall intent of this round was to attempt to reach a consensus with an IQR of one or less; however, a lack of consensus is just as important to identify when it indicates that divergent opinions exist.

Round Three Consensus Analysis

The third questionnaire was delivered to the seven panelists that participated in round two. The remaining three panelists, who had yet to participate, were removed from the group. All seven panelists responded for this round. Again, the arithmetic medians and IQRs were calculated for each theme as shown in Table 5. As seen, every IQR decreased enough to conclude that a consensus was reached on each of the themes presented during round three. While one of the drawbacks in a Delphi study is the potential of molding opinions, which would potentially remove true differences of opinion (Hsu & Sanford, 2007), panelists did not appear to conform to the group median ratings from round two as shown with the IQR variability in Table 5. The panelists also provided more clarifying comments than they did in the second round. Some of the comments provided some extra information or just simply explained why the panelist did not agree fully with the group. Regardless, consensus was reached, which concluded the Delphi study.

Table 5. Round Three Responses

Current Program: The following items were identified as strengths and weaknesses of current facility maintenance programs. (*agreement rating*)

	Theme	R2 Med	R2 IQR	R3 Med	R3 IQR
S	The RWP program is a good tool in that it provides notification on planned maintenance	4	2	4	0
W	Resources (people/time/$$) are inadequate to conduct timely maintenance and repair	4	1.5	4	0.5
	Current workload is overwhelming to keep up with PM and emergencies	4	1.5	4	1
	Focus is on wrong priorities such as high visibility but less critical tasks vs. planned maintenance	3	1.5	3	1

Ideal Program: Aspects of an efficient facility maintenance program identified in round 1. (*importance rating*)

	Theme	R2 Med	R2 IQR	R3 Med	R3 IQR
	Should be able to identify upcoming maintenance/repair that is above in-house scope (i.e. need to contract out)	4	2	4	0.5

Program Transition: The following items were identified in round 1 as needed to transition current facility maintenance programs towards more efficient programs. (*importance rating*)

	Theme	R2 Med	R2 IQR	R3 Med	R3 IQR
	Implement a modern & integrated IT system that accounts for material mgmt, work order mgmt, and facility condition	5	1.5	5	0.5
	'Worst-first' prioritization on *mission critical* facilities	4	1.5	4	0.5
	Manage and collect Facility Condition Assessments in order to build future condition predictions	4	1.5	4	0.5

Current CMMS: IWIMS was identified in round 1 to have the following strengths and weaknesses when it comes to its ability to support facility maintenance programs. (*agreement rating*)

	Theme	R2 Med	R2 IQR	R3 Med	R3 IQR
S	Tracks historical trend data (material costs, labor, etc.) assuming that data input was done correctly	4	1.5	4	0
	Provides good shop rate calculations when IWIMS is solely used	3	1.5	3	0.5
W	A drain on resources to operate and difficult to perform adequate data mining	5	1.5	5	0.5

Summary

This chapter presented the results from the three-round Delphi study, which was conducted to gather SME opinions on Air Force facility maintenance programs and CMMSs to strengthen a change message for the implementation of BUILDER™. An analysis of the qualitative responses provided results that show a consensus was reached on each theme component; however, only certain components contain suitable criteria for the change message in this research effort. The following chapter provides the conclusion to this research effort and includes a framework for the BUILDER™ implementation change message with the inclusion of the valid theme components from this analysis. The next chapter combines these responses with organizational change management criteria to develop a change message for the implementation of BUILDER™.

V. Discussion and Conclusion

Asset Management (AM) is an emerging concept that can help organizations adopt proactive facility maintenance programs. A realization for the need to adopt AM principles usually stems from a lack of adequate funding and support technologies, which in turn leaves various infrastructure components neglected (Vanier, 2001). The Air Force has shown an understanding of AM in the past few years with their recent organizational transformation (HQ USAF, 2014). However, additional change is required to realize the full potential of AM through the implementation of a Computerized Maintenance Management System (CMMS) called BUILDER™. Implementing multiple change initiatives at the same time can create additional difficulties; therefore, heightened attention must be focused on the change initiative (Beaudan, 2006).

This chapter combines the findings from the Delphi study along with organizational change management strategies identified in Chapter II. Change strategies and a change message, adapted from research by Armenakis and Harris (2009), are presented to provide Air Force Civil Engineer (CE) leadership with a framework for the implementation of BUILDER™, which addresses the first investigative question in this research effort:

1. What tactics and strategies can Air Force CE leadership employ to ensure a successful adoption and long-term use of BUILDER™?

However, prior to discussing available strategies and change message elements, it is important to emphasize upfront that the BUILDER™ implementation process is currently under way in the Air Force.

Change Strategies

Before focusing on the content of the change message, managers must consider which strategies to employ to help convey each of the change message elements. Three of the main strategies include active participation, persuasive communication, and management of information (Armenakis & Harris, 2002). This section addresses the importance of each strategy and identifies current Air Force measures utilizing the strategy along with recommendations.

Active Participation

The primary strategy to develop for delivering a change message is to involve change recipients in various phases of the change process (Armenakis & Harris, 2009). Ideally, one would build a multi-faceted working group to address many of the change message elements; however, this can be a difficult task in large organizations. Even though it may be difficult to involve the change recipients from the beginning, including them in molding the change initiative empowers change recipients and has an additional affect on their personal valence, which is discussed below (Armenakis & Harris, 2009).

Specific to the BUILDER™ implementation, the Air Force conducted a test case with a few installations in November 2013. This test case was centered on facility condition assessments and the initial use of the BUILDER™ software. The results provided valuable feedback to the organization leading the implementation, the Air Force Civil Engineer Center (AFCEC). This test case is a good example of two of the active participation forms: enactive mastery (i.e., gradually build skills) and participation in decision-making (Armenakis & Harris, 2002). The AFCEC also provides numerous avenues for hands on training with BUILDER™ (AFCEC, 2014). The third participation form, vicarious learning, is currently being accomplished using an online site for personnel at the installation level to share their lessons learned (PEO C3T MilTech Solutions, n.d.). Allowing change recipients to observe "others applying new productive techniques enhances [their own] confidence in adopting the innovation" (Armenakis et al., 1993:686).

Recommendation: The AFCEC should continue to provide avenues for hands on training which develops enactive mastery with the new Information Technology (IT) system. This training becomes important to ensure that the change effort extends beyond the initial implementation stage (Jacobs & Russ-Eft, 2001). Lessons learned or case studies from other installations or external organizations that are currently utilizing BUILDER™ should also be provided to the CE community. Finally, as joint basing becomes more prevalent in the future, it would be beneficial for each defense service to share their experiences with BUILDER™. Doing so could increase efficiencies as like functions begin to be combined in a joint atmosphere. One example of intra-service learning is the inclusion of the Marine Corps facility condition assessment manual on the AFCEC BUILDER™ website (Parsons & TEC inc, 2011). This is a clear start for providing vicarious learning sources to Air Force CE personnel.

Persuasive Communication

Communication is another important strategy for conveying the change message using speeches, memos, or even non-verbal means (Armenakis & Harris, 2009; By, 2007). Communication is the primary method that informs the workforce on the various aspects of the change. Additionally, the implicit side of communication is just as important to create an atmosphere that does not contain a management-against-workforce mentality, rather a unified "we-are-all-in-the-same-boat mentality" (By, 2007:6).

The Air Force currently operates a powerful online communication tool to reach the CE community regarding many current and important topics to include the CE Transformation. The CE Portal provides the latest guidance, factsheets, information on the CE Transformation, as well as other important information from CE leadership (CE Portal, n.d.). The AFCEC has also produced online video briefings that explain specific CE Transformation details (AFCEC, 2014), as well as a website dedicated specifically to information on BUILDER™ (AFCEC, n.d.). Together, these methods can provide an efficient way to communicate many of the areas of the change message.

Recommendation: As mentioned in Chapter II, mid-level change agents should be utilized to help advance the implementation process (Lam & Schaubroeck, 2000). The use of "respected peers, or opinion leaders, [can] increase the probability of successful organizational change" (Hammond, Gresch, & Vitale, 2011:492). Specific to IT change, these opinion leaders could also act as IT power users and be a part of integrated program teams (IPT) which can be very beneficial during communication efforts (Kundra, 2010). The Air Force is currently utilizing power users at the installation level for implementation of other next generation (NextGen) IT software. These power users participate in specific IT training, relay communication between leadership and end users, and provide local support to end users (CE Portal, n.d.). Similar efforts could greatly enhance the initial acceptance and continued utilization of BUILDER™. Furthermore, these mid-level change agents can provide a face-to-face dialogue with the technicians at the installation level. A direct communication source and change advocate at the base should sustain or even enhance the overall change inertia.

Management of Information

Managing information has an important and close relationship to the communication process. Incorrect or lacking information can have negative effects on communicating the change message. In fact, lack of information can quickly instill cynicism among change recipients (Reichers et al., 1997). However, if both internal and external information is managed efficiently, it can provide a means for vicarious learning as mentioned in a previous example (Armenakis & Harris, 2009).

Recommendation: First, as the change process evolves, general guidance doctrine is also expected to change; therefore, it is important to continue to disseminate these updates. Utilizing mid-level change agents, as described above with communication, can make this process more efficient. Utilizing the CE Portal and AFCEC website are also valuable avenues to organize and distribute information on the BUILDER™ implementation process. Finally, compiling information from external sources on similar implementation efforts can greatly strengthen the efficacy portion of the change message, which is discussed in the next section.

Change Message

The framework of a change message consists of five components that "shape an individual's motivations, positive (readiness and support) or negative (resistance), toward the change" (Armenakis & Harris, 2002:170). Clear communication of this vision is vital to capture the attention of change recipients and reduce potential cynicism (Kotter, 1995).

The sections below present important factors for each element to include recent information from the ongoing change and response data from the Delphi study.

Discrepancy

One of the first steps in any change process should involve identification of a gap between the organization's status quo and desired end-state (Armenakis et al., 2007). Specific to Air Force CE units, new AM operating procedures are already in the process of being implemented. CE leadership has identified issues that existed with prior facility management procedures and developed a new organizational structure to accommodate AM principles (CE Portal, n.d.; HQ USAF, 2014). This research effort explored discrepancy by identifying a desired end-state compared to current operations. The overall discrepancy element addresses the first and second investigative questions.

2. According to Air Force CE base-level Subject Matter Experts (SMEs), what defines a successful facility maintenance program
3. What is the gap between current Air Force facility maintenance programs and an ideal successful facility maintenance program?

As mentioned above, the Air Force is focused on adopting AM principles that will launch the organization into a proactive and efficient facility management organization. Since BUILDER™ is a related component to AM principles, much of the framework has already been provided through the CE Transformation Programming Plans (P-Plan) (HQ USAF, 2014). The inclusion of BUILDER™ in the transformation resulted from the identification of issues with current operating practices. The Office of the Deputy Under Secretary of Defense (ODUSD) specifically identified a deficiency in current operations in that "facility condition index data…lacks credibility as a measure of DoD facility quality" (Kendall, 2013:1). This ODUSD guidance identifies the discrepancy and requires each defense component to utilize BUILDER™ to compute standardized facility conditions.

Along with a top-level directive, it is also important to assess the organization at the workforce level. The Delphi study revealed numerous observations that identify discrepancy criteria. As mentioned in previous chapters, part of the study explored criteria based on current facility maintenance programs and CMMS. SMEs provided insight into some general issues in both areas. The general theme for facility maintenance programs appears to identify that the current workforce is stretched thin and focused on priorities other than Preventive Maintenance (PM). Additionally, the current IT systems appear to be unable to support maintenance programs. The Delphi panelists provided the following themes:

- Resources (time/money/people) are inadequate to conduct timely maintenance and repair
- Workload is overwhelming to keep up with PM while responding to other requests
- IT systems are outdated
- IT systems do not efficiently communicate with each other, higher commands, or sister services
- IT system cannot perform required tasks and doesn't meet current needs
- IT system is a drain on resources (manpower/time)

The Delphi panel also identified some expectations of these facility maintenance programs and CMMS. Aligned with the overall CE Transformation, the first few results below identify a focus on PM and moving towards a future planning stance with facility maintenance. The IT systems are expected help the organization incorporate AM principles into daily maintenance activities. Additionally, one comment on the current programs stated that the CE Transformation is moving the organization into a positive direction focused more on PM. This comment indicates that pre-acceptance seems to exist with the ongoing transformation, which is a positive aspect to note. The Delphi panelists provided the following expectation themes:

- Focuses on PM that is based on system/component performance
- Identifies when maintenance should be performed
- Enables development of investment plans
- IT systems are easy to manage and are compatible with other IT systems
- IT systems track property, equipment, and resources
- IT systems export usable metrics to help managers advocate for funding
- IT systems compute current and future component conditions

Recommendation: An important first step in the change message is to clearly explain the operational gap that is bringing about the change. Basic AM principles, the ODUSD directive, and Delphi panel input all provide a strong basis for the discrepancy element. Communicating these discrepancies to the CE community is crucial to shift the organizational readiness towards an acceptance posture. Before anyone can process the additional elements of the change message, they must understand the reasoning behind the change.

Appropriateness

Change agents must identify how the change fits the needs of, or is appropriate for, the organization's new path. For this research effort, this step involved highlighting the various benefits that BUILDER^{TM} provides, most of which were identified in Chapter II. This is a crucial step to convince the CE community on the benefits from

BUILDER™, because simply identifying that the ODUSD requires its use may not gain traction. Instead, BUILDER™ use should be approached as an AM-focused link in the overall CE transformation. This section also addresses the third investigative question.

4. What is the gap between current Air Force facility maintenance programs and an ideal successful facility maintenance program?

A few of the expectations of a CMMS, mentioned above, are being met by BUILDER™. The program is easy to operate, tracks property and equipment, computes conditions, and exports valuable data that can be used to advocate for projects. The AFCEC began initial implementation stages of BUILDER™, starting with the test case mentioned in beginning of this chapter. The AFCEC also presented a risk-focused project-scoring model that is AM focused and specifically utilizes data output from BUILDER™ (AFCEC, 2014). Figure 17 demonstrates the risk model with seven projects in 2014. The consequence of failure is the commander's risk assessment that characterizes consequence, and the probability of failure is the engineering risk assessment that is based on condition data. Furthermore, the size of each dot represents a cost savings value. In this situation, projects are simply compared in an objective way based on risk (AFCEC, 2014). BUILDER™ not only identifies economically feasible maintenance actions, but decision-making also becomes more objectively based when BUILDER™ is combined with the above risk model. This satisfies a few of the SME inputs from the Delphi study (e.g., targeted condition-based maintenance and worst-first prioritization for mission critical facilities).

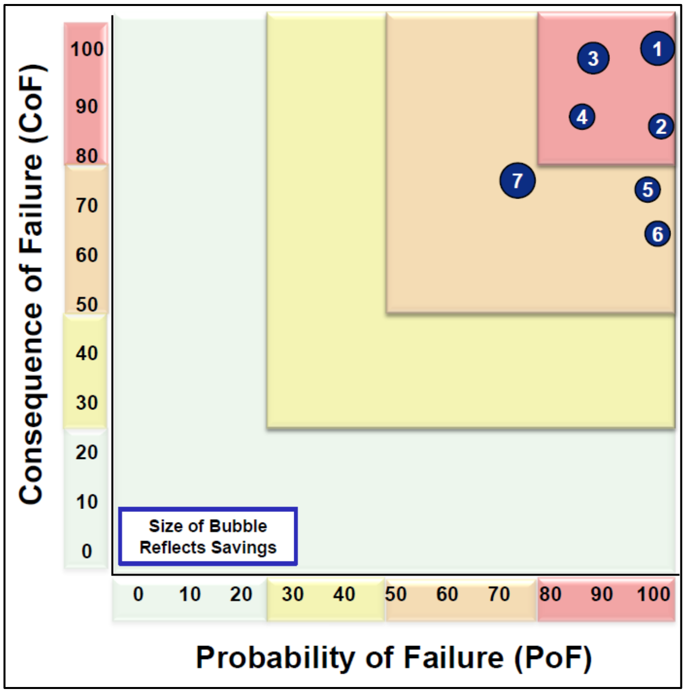


Figure 17. Standardized Risk Model (AFCEC, 2014)

Additionally, BUILDER™ can be used to demonstrate the benefits of focusing on condition-based maintenance (CBM) and capitalizing on investments made during the economic sweet spot as shown in Figure 4. A proof-in-concept test case based on an inventory of a real world facility along with a fictional condition state was analyzed with BUILDER™. A project list of 15 items was developed and sorted based on the CI (i.e., worst first) as shown in Table 6. Some key specifics of the table follow. First, the *Action* column is based on the Return on Investment (ROI) for that work item. For example, BUILDER™ chose a repair for project K because the ROI was above the replacement ROI of 100%. The *Cost to Defer* column was developed by running the project list twice, once for the current year and again for the next year with the assumption that nothing was accomplished this year. For most instances, deferring the project one year creates an increase due inflation. However, in some of the repair cases, BUILDER™ has determined that if the project is deferred one year, the CI will decrease beyond the economic sweet spot, thus a replacement would be required. For example, for project N, the repair this year will cost $15,500, but deferring it to next year will require a full replacement, which increases the cost by $102,500.

Table 6. BUILDER™ Produced Project List Sorted by Worst First

Project	Action	ROI	Cost	Cumulative Cost	Cost to Defer
A	Replace	100%	$173,000	$173,000	$3,000
B	Replace	100%	$111,000	$284,000	$2,000
C	Replace	100%	$23,500	$307,500	$500
D	Replace	100%	$8,100	$315,600	$100
E	Replace	100%	$79,000	$394,600	$1,000
F	Replace	100%	$93,000	$487,600	$2,000
G	Replace	100%	$171,000	$658,600	$3,000
H	Repair	101%	$4,200	$662,800	$12,300
I	Replace	100%	$3,200	$666,000	$50
J	Repair	108%	$60,000	$726,000	$0
K	Repair	151%	$5,300	$731,300	$34,700
L	Replace	100%	$5,200	$736,500	$100
M	Repair	151%	$8,600	$745,100	$56,400
N	Repair	152%	$15,500	$760,600	$102,500
O	Replace	100%	$3,950	$764,550	$100

If a budget level is set at $400,000 in this test case, the first five projects will receive funding. While these are truly the components in the worst condition, the list does not address any of the projects that are in the economic sweet spot. Therefore, the project list was re-sorted based on ROI and then CI as shown in Table 7. As seen with this situation, the $400,000 funding addresses all of the projects that fall within the economic sweet spot as well as two of the critical CI projects (i.e., projects A and B) for a total of seven projects. This test case illustrates a more efficient use of funding, and while it is solely based on CI and ROI, other factors such as mission criticality could be included in the decision process. With proper prioritization schemes, investments could be made to those projects that must be done and include these instances where CBM can be provided at the most economically advantageous time.

Table 7. BUILDER™ Produced Project List Sorted by Highest ROI

Project	Action	ROI	Cost	Cumulative Cost	Cost to Defer
N	Repair	152%	$15,500	$15,500	$102,500
K	Repair	151%	$5,300	$20,800	$34,700
M	Repair	151%	$8,600	$29,400	$56,400
J	Repair	108%	$60,000	$89,400	$0
H	Repair	101%	$4,200	$93,600	$12,300
A	Replace	100%	$173,000	$266,600	$3,000
B	Replace	100%	$111,000	$377,600	$2,000
C	Replace	100%	$23,500	$401,100	$500
D	Replace	100%	$8,100	$409,200	$100
E	Replace	100%	$79,000	$488,200	$1,000
F	Replace	100%	$93,000	$581,200	$2,000
G	Replace	100%	$171,000	$752,200	$3,000
I	Replace	100%	$3,200	$755,400	$50
L	Replace	100%	$5,200	$760,600	$100
O	Replace	100%	$3,950	$764,550	$100

Recommendation: Effort should be focused on providing the powerful computing benefits that BUILDER™ provides. Some of these benefits may not become guidance (i.e., directed for use) but can provide base-level personnel with forecasting methods to help advocate for funds. This is a key stage to gain the buy-in from change recipients. Additionally, updated guidance must be disseminated throughout the change process. However, some criteria that were identified during the Delphi study are not accomplished solely utilizing BUILDER™. The themes listed below are common in most CMMS but not in BUILDER™. An assumption in this research effort is that the IT criteria below are addressed by the NextGen IT implementation and that it will be linked to BUILDER™. Communicating that these limitations with BUILDER™ are covered by the NextGen IT system can also help the change recipient buy-in.

- Tracks materials and manpower
- Tacks the work orders from cradle to grave
- Communicates with other IT systems

Self-Efficacy

In self-efficacy, leaders must reassure their personnel that they are themselves able to accomplish the new tasks and goals. CE leaders must re-assure personnel at the squadrons and staffs that they are capable of implementing, and more importantly, operating BUILDER™. Research shows that individuals tend to avoid a task when they lack confidence in their ability to accomplish it (Armenakis et al., 2007). Some of tactics are available to build confidence within the workforce. First, presenting lessons learned and case studies from other defense services can provide a generalized 'well if they can do, so can we' attitude. A second tactic falls in line with the next change message element where leadership can provide any resources needed to accomplish the task.

The initial brief by the AFCEC provides a good start to convincing the CE community that this change effort can take place. Specifically, they provide some recommendations for success to include getting smart with BUILDER™, narrow focus to a manageable level, and other project development specifics (AFCEC, 2014). Additionally, feedback provided from the base-level identified that excessive effort is required to assess the condition of every component in every facility. This, in turn, produced recommendations for facility managers to *narrow their focus*, trust their expert technicians, and perform a 'targeted' inventory assessment (AFCEC, 2014). In other words, personnel at the installation should choose the facilities that are the most important to them in these beginning stages of implementation. The AFCEC brief also included a base-level technician explaining their experiences with BUILDER™ during the test case mentioned earlier (AFCEC, 2014).

<u>Recommendation</u>: The best way to continue to build efficacy is continual communication of the change process. As potential recommendations from the base-level are made and incorporated into business rules, updates must be conveyed to the career field. These updates show that the process is being made better based on feedback and participation that should help change recipients see the progress and believe that success is possible. Additionally, certain resources may be required and providing them can build efficacy in the overall change process.

Principal Support

Leadership support is yet another important element in the change message (Armenakis & Harris, 2009). This support involves providing additional resources and a continued commitment from the change agent as well as mid-level change agents

(Armenakis & Harris, 2002). A hierarchical organization like the Air Force contains many levels of leadership and if the change message is only presented from the top, it can be difficult for the lowest levels to perceive that principal support. One study identified that poor leadership, lack of commitment, and even too many layers of leadership were some reasons for change implementation failure (Arora & Kumar, 2000).

Recommendation: As previously mentioned, each level of leadership should act as mid-level change advocates. This change agent hierarchy scheme can be a powerful strategy not only for communication but to build an atmosphere where principal support is perceived at a level where change recipients can physically interact with leadership. Additionally, IPTs at installation levels can provide a direct line of support as guidance and procedures evolve along the change process. One of the more difficult areas with this element, however, is providing requested resources. As the budget continues to decrease, this can become a difficult task. Even so, it is still important to provide as much assistance to base-level technicians as possible to sustain the change inertia.

Personal Valence

Finally, it is important to identify the intrinsic personal value that the change will have for the change recipients (Armenakis & Harris, 2009). This is a potentially difficult area to address regarding the implementation of BUILDER™, but one area that can provide intrinsic valence is technician input. During the test case, technicians, with many years of experience, were asked to assist in a decision process. When thanked for their input, one technician mentioned how he had rarely been asked for his advice regarding these matters and that he was excited to participate (AFCEC, 2014). This demonstrates that technicians are passionate of their work and assisting in the change process can boost their job satisfaction.

Recommendation: Involving technician input, especially in the early implementation phases, can provide valuable benefits. This inclusion should give pride to technicians, as they will have a strong voice in change process and the quality of the data in BUILDER™. Additionally, the workforce should experience a more structured workload as reactive maintenance tasks are replaced by a proactive and planned program, which addresses some of the Delphi study SME input. The overall job satisfaction may also have a positive trend as the technicians begin to work with state of the art IT systems and facility management principles. It is important to communicate these worker benefits along with pride in the fact that resource use will become more efficient thus focusing taxpayer's money more appropriately. Finally, a new rewards and benefits system could be developed that focuses on new AM focused criteria.

Future Research Opportunities

As previously mentioned, the Air Force is currently progressing with an overall CE Transformation, which now also includes BUILDER™. While many change message elements are currently being addressed, the message itself is not designed to be static. As the change process evolves, so should the change message and the strategies used to convey the message. To update and improve the message and strategies, an assessment of the overall organization is required (Armenakis & Harris, 2009). Future research can accomplish this assessment task by employing a mass survey to personnel in charge of implementing BUILDER™ at the base-level. The survey could focus on the presence of any negative or positive emotions among the change recipients as well as their view on perceived organizational support. Many other change management factors can be included as well depending on the direction of the research. Results from the survey could help the AFCEC make any necessary course corrections to the BUILDER™ implementation or even the overall CE Transformation.

Another potential area to explore involves another geographic based IT system. Geobase is a geographic information system program that tracks all of the assets on an installation. This visual tool not only useful for tracking assets, it becomes vital for planning initiatives. Currently, the system is a standalone program. Exploration could be made into the integration of this IT system with BUILDER™ or the upcoming NextGen IT program.

A final suggestion for future research involves a comparison between BUILDER™ life-cycle analysis and aircraft maintenance life-cycle analysis. Research could investigate how facility life-cycle analysis could benefit from standard processes currently performed in the aircraft maintenance field. For instance, when a certain airframe meets a flight hour threshold, it is sent to the depot for maintenance. Similar limits could be investigated regarding facility components and when a defined limit is reached, adequate funding is provided to repair the component.

Conclusion

This research emphasized the need to adopt facility AM principles to transition reactive maintenance focused programs to a proactive state. It presented an organizational change management approach based on literature and SME input to identify change management strategies and construct a change message to implement BUILDER™. The AFCEC is already utilizing some of the change strategies to convey the change message, but as the change implementation progresses, the change message will need to evolve as well. Strengthening the change management strategies will also be crucial to continue conveying the message to the CE community to ensure effective institutionalization of BUILDER™. Overall, adequate progress is being made in the early implementation stages of BUILDER™, and continued focus on all elements of the change message and dissemination strategies will improve the program's acceptance and utilization in the career field.

Appendix A. BUILDER™ Implementation – Delphi Study Round #1

Thank you for agreeing to participate in this Delphi Study. The purpose of this study is to perform research relating to AF civil engineer program implementation. The objective is to utilize organization change management practices and determine key criteria that will aid the CE community in the institutionalization of a new facility management software. The sponsor for this research is Mr. Scott Ensign, AFCEC.

Please note the following:

Benefits and risks: There are no personal benefits or risks for participating in this study. Your participation in completing this questionnaire should take 30-45 minutes per round.

Confidentiality: Your responses are completely confidential, and your identity will remain anonymous. No individual data will be reported; only data in aggregate will be made public. Individual data will be kept in a secure, locked cabinet to which only the researchers will have access. If you have any questions or concerns about your participation in this study, please contact:

STANTON P. BROWN, Captain, USAF GEM Student Graduate School of Engineering and Management Air Force Institute of Technology Wright-Patterson AFB, OH Cell 937-207-2280	ALFRED E. THAL, Jr., PhD Associate Professor of Engineering Management Graduate School of Engineering and Management Air Force Institute of Technology Wright-Patterson AFB, OH DSN 312-785-3636 ext 7401 Comm 937-255-3636

Voluntary consent: Your participation is completely voluntary. You have the right to decline to answer any question, to refuse to participate, or to withdraw at any time. Your decision of whether or not to participate will not result in any penalty or loss of benefits to which you are otherwise entitled. Completion of the questionnaire implies your consent to participate.

Background:

Each of the Defense Components currently utilizes various methods to assess facility conditions and resulting Facility Condition Indexes (FCI). This inconsistency has led the Under Secretary of Defense for Acquisition, Technology and Logistics (ODUSD(AT&L)) to question the credibility of the overall Department of Defense's (DoD) facility quality measures. Therefore, the ODUSD(AT&L) is requiring that all Defense Components adopt the Sustainment Management System (SMS) called BUILDER™.

This SMS utilizes objective and repeatable inspections on facility components to verify their predicted condition based on its expected stage in the life-cycle. The detail and frequency of these inspections are not fixed but are dependent on the knowledge of component criticality, expected & measured rate of deterioration, and remaining maintenance & service life of the various facility components. BUILDER™ computes individual component condition indexes (CI) which are combined to provide an overall building condition index (BCI). The BCI is an objective value that allows BUILDER™ to compile an annual work plan for repair and replacement projects in a given facility. The work plan is developed based on the career field criteria such as component criticality, facility MDI, CI, etc.

Furthermore, BUILDER™ can also provide useful long term planning scenarios that depict situations of future funding cuts as well as benefits of repairing components vs. replacing them. Most importantly, BUILDER™ provides a quick outlook on the overall health of each facility on an installation. This understanding will ultimately aid decision makers and facility maintenance personnel to foster a proactive maintenance program that will meet today's asset management needs.

By responding, you have the opportunity to shape how the AF CE functional community takes advantage subject matter expert input to create a successful program implementation plan. Thank you for participating in this study and helping apply those lessons and the perspective you have honed through years of CE service. I appreciate your time and candid responses.

Process:

1. Please complete this questionnaire **electronically** and return it to me at: **stanton.brown@afit.edu** no later than **20 December 2013.** If you have questions, I can be reached primarily via e-mail or at my cell #: 937-207-2280.

2. This questionnaire is an instrument of a Delphi study. The Delphi method is an iterative, group communication process which is used to collect and distill the judgments of experts using a series of questionnaires interspersed with feedback. The questionnaires are designed to focus on problems, opportunities, solutions, or forecasts. Each questionnaire is developed based on the results of the previous questionnaire. The process continues until the research question is answered. For example, when consensus is reached and sufficient information has been exchanged. This usually takes, on average, 3 rounds.

3. There are seven primary questions (broken into two categories) for this round. **Please elaborate fully on your answers** and feel free to provide additional insight, if you deem it relevant, even if it is not specifically requested by the questions. Once all interview responses are received, I will analyze them for common themes and compile them in aggregate form. You will be asked to review and revise your initial responses based on the collective responses provided by the entire group. Subsequent rounds will be announced as needed and all research is scheduled to conclude by **12 February 2014**.

Research questions:

Please answer the following questions as clearly and concisely as possible without omitting critical information or rationale required for the group to consider your opinions. Base your responses on your own personal experiences and perceptions.

Facility Maintenance Programs

1. Consider your base's current facility maintenance program. In a few sentences, how would you design an ideal facility maintenance program?
2. Please identify a few metrics (standard practice or customized) that you would use to gauge success.
3. Based on your experience, how effective is the current facility maintenance program? Please identify any key strengths and weaknesses.
4. What do you believe is needed in order to strengthen the current facility maintenance program (i.e. transition towards an ideal program from question 1)?

Sustainment Management System

5. IWIMS is considered as a type of a Sustainment Management System (SMS). How well does this SMS meet your needs in managing a facility maintenance program?
6. Please identify a few key IWIMS capabilities that you find valuable as well any capabilities that are not useful or could be improved upon.
7. What are a few key capabilities that you expect from an SMS to properly manage your facility maintenance program?

Appendix B. BUILDER™ Implementation – Delphi Study Round #2

Thank you again for agreeing to participate in this Delphi Study. The purpose of this study is to perform research relating to AF civil engineer program implementation. The objective is to utilize organization change management practices and determine key criteria that will aid the CE community in the institutionalization of new facility management software. The sponsor for this research is Mr. Scott Ensign, AFCEC.

Please note the following:
Benefits and risks: There are no personal benefits or risks for participating in this study. Your participation in completing this follow-up questionnaire should take ***less than 15 minutes***.

Confidentiality: Your responses are completely confidential, and your identity will remain anonymous. No individual data will be reported; only data in aggregate will be made public. Individual data will be kept in a secure, locked cabinet to which only the researchers will have access. If you have any questions or concerns about your participation in this study, please contact:

STANTON P. BROWN, Captain, USAF GEM Student Graduate School of Engineering and Management Air Force Institute of Technology Wright-Patterson AFB, OH Cell 937-207-2280	ALFRED E. THAL, Jr., PhD Associate Professor of Engineering Management Graduate School of Engineering and Management Air Force Institute of Technology Wright-Patterson AFB, OH DSN 312-785-3636 ext 7401 Comm 937-255-3636

Voluntary consent: Your participation is completely voluntary. You have the right to decline to answer any question, to refuse to participate, or to withdraw at any time. Your decision of whether or not to participate will not result in any penalty or loss of benefits to which you are otherwise entitled. Completion of the questionnaire implies your consent to participate.

Purpose:
Responses from the first round questionnaire were centered on identifying current vs. desired facility maintenance program characteristics and IT system expectations. The content of the responses were subsequently analyzed and major themes summarized. As a reminder, the questions from round 1 were:

1. Consider your base's current facility maintenance program. In a few sentences, how would you design an ideal facility maintenance program?
2. Please identify a few metrics (standard practice or customized) that you would use to gauge success.
3. Based on your experience, how effective is the current facility maintenance program? Please identify any key strengths and weaknesses.
4. What do you believe is needed in order to strengthen the current facility maintenance program (i.e. transition towards an ideal program from question 1)?
5. IWIMS is considered as a type of a Sustainment Management System (SMS). How well does this SMS meet your needs in managing a facility maintenance program?
6. Please identify a few key IWIMS capabilities that you find valuable as well any capabilities that are not useful or could be improved upon.
7. What are a few key capabilities that you expect from an SMS to properly manage your facility maintenance program?

Process:
1. This follow-up questionnaire is an instrument of a Delphi study. The Delphi method is an iterative, group communication process which is used to collect and distill the judgments of experts using a series of questionnaires interspersed with feedback. Questionnaires are designed to focus on problems,

opportunities, solutions, or forecasts. Each follow-up questionnaire is developed based on the results of the previous questionnaire. The process continues until the research question is answered. This usually takes, on average, 3 rounds.

2. The questionnaire below was built from responses from round 1. Each theme contains various items in no particular ranked order. **Please rate each item** and feel free to provide additional insight, if you deem it relevant, even if it is not specifically requested by the questions. Once all interview responses are received, I will analyze them for consensus. You may also review and revise your initial responses based on the collective responses provided by the entire group if desired. Subsequent rounds will be announced as needed and all research is scheduled to conclude by **19 February 2014**.

3. Please complete this questionnaire **electronically** and return it to me at: **stanton.brown@afit.edu,** no later than **7 February 2014.** If you have questions, I can be reached primarily via e-mail or at my cell #: 937-207-2280.

Directions:
This questionnaire utilizes two variations of the 5-point Likert scale as shown below. Details on each theme are explained followed by the specific Likert scale. The first three themes (T1-3) relate to ***facility maintenance programs***, and the last two themes (T4-5) relate to ***IT Systems***.

Common Acronyms
PM – Preventive Maintenance
CMMS – Computerized Maintenance Management System

Rating Scale 1	Rating Scale 2
5 – Strongly Agree	5 – Very Important
4 – Agree	4 – Important
3 – Neutral	3 – Moderately Important
2 – Disagree	2 – Of little Importance
1 – Strongly Disagree	1 – Unimportant

- -

Questionnaire #2

T1. **Current Program**: The following items were identified as strengths and weaknesses of current facility maintenance programs. Please rate your ***agreement*** on each item.

5 - Strongly Agree, 4 - Agree, 3 - Neutral, 2 - Disagree, 1 - Strongly Disagree

Strength	Rating
Technician & engineer 'Can-do' attitudes keep facilities operational with no mission failure	
CE transformation focuses on PM and overall organizational prioritization (AF/MAJCOM wide)	
RWP program focuses work on PM	

Weakness	Rating
Resources (people/time/money) are inadequate	
Current workload is overwhelming	
Focus is placed on the wrong priorities (i.e. not on PM)	
Current IT systems are outdated	
Current IT systems do not effectively communicate with each other	
Comments:	

T2. **<u>Ideal Program</u>**: Aspects of an efficient facility maintenance program were identified in round 1. Please rate the following items by ***level of importance*** as you perceive them at this time.

5 - Very Important, 4 - Important, 3 - Moderately Important, 2 - Of Little Importance, 1 – Unimportant

Component	Rating
Should be able to account for & prioritize resources (money, material, & manpower)	
Identifies when maintenance should be performed	
Enables the development of an investment plan for maintenance requirements that are short, mid, & long term	
Focuses on PM	
PM should focus on system/component performance not pre-determined frequencies (i.e. manufacturer recommendations)	
Enables managers to predict the consequences of their decisions	
Identifies maintenance that is above in-house scope	
Centralized management, decentralized execution	
PM should be based on standardized AF directives or manufacturer recommendations	
Uses IT systems that are easy for day-to-day use	
Comments:	

T3. **<u>Transition (T1 to T2)</u>**: The following items were identified in round 1 as needed to transition current facility maintenance programs (T1) towards more efficient programs (T2). Please rate the following items by ***level of importance*** as you perceive them at this time.

5 - Very Important, 4 - Important, 3 - Moderately Important, 2 - Of Little Importance, 1 – Unimportant

Component	Rating
Additional resources (money, manpower, component tracking tools)	
Focus on intentional & targeted maintenance (i.e. pre-planned & based on life-cycle conditions)	
Implement a modern IT system	
Prioritize projects that are 'worst-first'	
Implement a system provides data to help communicate the impact & importance of PM	
Need to collect & manage Facility Condition Assessments	
Comments:	

T4. **<u>Current CMMS</u>**: IWIMS was identified in round 1 to have the following strengths and weaknesses when it comes to its ability to support facility maintenance programs. Please rate your ***agreement*** on each component.

5 - Strongly Agree, 4 - Agree, 3 - Neutral, 2 - Disagree, 1 - Strongly Disagree

Strength	Rating
Tracks historical trend data (material costs, labor, etc.)	
People are familiar with it and know how to use it	
Contains valuable information	
Enables CES to perform their mission	
Provides good shop rate calculations	
Weakness	**Rating**
Difficult to use	
Can't perform required tasks / doesn't meet current needs	
A drain on resources to operate / data mine	
Doesn't efficiently communicate to other IT systems	
It's an internal system that doesn't communicate with sister services or higher commands	
Outdated	
Comments:	

T5. **<u>Ideal CMMS</u>**: The follow items were identified as expected capabilities of a CMMS. Please rate the following items by ***level of importance*** as you perceive them at this time.

5 - Very Important, 4 - Important, 3 - Moderately Important, 2 - Of Little Importance, 1 – Unimportant

Capability	Rating
Identifies future maintenance work requirements	
Exports usable metrics/reports to advocate for funds	
Computes current & future component conditions	
Prioritizes work	
Tracks material	
Tracks work order requests (332s) through the whole cycle	
Compatible with other IT systems	
Universal across the services	
Easy to manage and input data	
Tracks real property & equipment inventory	
Comments:	

Appendix C. BUILDER™ Implementation – Delphi Study Round #3

Thank you again for agreeing to participate in this Delphi Study. The purpose of this study is to perform research relating to AF civil engineer program implementation. The objective is to utilize organization change management practices and determine key criteria that will aid the CE community in the institutionalization of new facility management software. The sponsor for this research is Mr. Scott Ensign, AFCEC.

Please note the following:

Benefits and risks: There are no personal benefits or risks for participating in this study. Your participation in completing this follow-up questionnaire should take ***less than 5 minutes***.

Confidentiality: Your responses are completely confidential, and your identity will remain anonymous. No individual data will be reported; only data in aggregate will be made public. Individual data will be kept in a secure, locked cabinet to which only the researchers will have access. If you have any questions or concerns about your participation in this study, please contact:

STANTON P. BROWN, Captain, USAF GEM Student Graduate School of Engineering and Management Air Force Institute of Technology Wright-Patterson AFB, OH Cell 937-207-2280	ALFRED E. THAL, Jr., PhD Associate Professor of Engineering Management Graduate School of Engineering and Management Air Force Institute of Technology Wright-Patterson AFB, OH DSN 312-785-3636 ext 7401 Comm 937-255-3636

Voluntary consent: Your participation is completely voluntary. You have the right to decline to answer any question, to refuse to participate, or to withdraw at any time. Your decision of whether or not to participate will not result in any penalty or loss of benefits to which you are otherwise entitled. Completion of the questionnaire implies your consent to participate.

Purpose:

Responses from the first two rounds have been analyzed. While consensus has been reached most of the items for the previous round, there are still 11 themes that require attention. Consensus is determined through the arithmetic median score and the inter-quartile range (IQR). The IQR is the range that contains the answers of the middle 50 percent of the respondents. For this research effort an IQR less than or equal to 1 is desired.

Process:

1. This is the **3rd and Final Round** of the study. Once all questionnaire responses are received, an analysis of the Round 3 will be conducted and the results will be summarized and sent to you in a final report.

2. Please complete this questionnaire **electronically** and return it to me at: **stanton.brown@afit.edu,** as soon as possible but no later than **17 February 2014.** If you have questions, I can be reached primarily via e-mail or at my cell #: 937-207-2280.

Directions:

Below are the remaining items that require re-rating. Each of these had an IQR above 1 signifying that consensus has not been reached. Each item is presented with your response and the group median response. Also, clarification has been added to each theme.

Common Acronyms

PM – Preventive Maintenance

CMMS – Computerized Maintenance Management System

Rating Scale 1
5 – Strongly Agree
4 – Agree
3 – Neutral
2 – Disagree
1 – Strongly Disagree

Rating Scale 2
5 – Very Important
4 – Important
3 – Moderately Important
2 – Of little Importance
1 – Unimportant

Questionnaire #3:

T6. **Current Program**: The following components were identified as strengths and weaknesses of current facility maintenance programs. Please rate your ***agreement*** on each component.

5 - Strongly Agree, 4 - Agree, 3 - Neutral, 2 - Disagree, 1 - Strongly Disagree

Your Rating	Groups Rating	Strength	New Rating/Comment(s)
	4	The RWP program is a good tool in that it provides notification on planned maintenance	

		Weakness	
	4	Resources (people/time/$$) are inadequate to conduct timely maintenance and repair	
	4	Current workload is overwhelming to keep up with PM and emergencies	
	3	Focus is on wrong priorities such as high visibility but less critical tasks vs. planned maintenance	

T7. **Ideal Program**: Aspects of an efficient facility maintenance program were identified in round 1. Please rate the following items by ***level of importance*** as you perceive them at this time.

5 - Very Important, 4 - Important, 3 - Moderately Important, 2 - Of Little Importance, 1 – Unimportant

Your Rating	Groups Rating	Component	New Rating/Comment(s)
	4	Should be able to identify upcoming maintenance/repair that is above in-house scope (i.e. need to contract out)	

T8. **Transition (T1 to T2)**: The following identified items are needed to transition current facility maintenance programs (T1) towards more efficient programs (T2). Please rate the following items by ***level of importance*** as you perceive them at this time.

5 - Very Important, 4 - Important, 3 - Moderately Important, 2 - Of Little Importance, 1 – Unimportant

Your Rating	Groups Rating	Component	New Rating/Comment(s)
	5	Implement a modern & integrated IT system that accounts for material mgmt, work order mgmt, and facility condition	
	4	'Worst-first' prioritization on *mission critical* facilities	
	4	Manage and collect Facility Condition Assessments in order to build future condition predictions	

T9. **Current CMMS**: IWIMS was identified to have the following strengths and weaknesses when it comes to its ability to support facility maintenance programs. Please rate your ***agreement*** on each component.

5 - Strongly Agree, 4 - Agree, 3 - Neutral, 2 - Disagree, 1 - Strongly Disagree

Your Rating	Groups Rating	Strength	New Rating/Comment(s)
	4	Tracks historical trend data (material costs, labor, etc.) assuming that data input was done correctly	
	3	Provides good shop rate calculations when IWIMS is solely used	

		Weakness	
	5	A drain on resources to operate and difficult to perform adequate data mining	

Appendix D. AFIT Human Subjects Exemption Approval

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY (AETC)

MEMORANDUM FOR DR AL THAL

FROM: John J. Elshaw, Ph.D.
AFIT IRB Research Reviewer
2950 Hobson Way
Wright-Patterson AFB, OH 45433-7765

SUBJECT: Approval for exemption request from human experimentation requirements (32 CFR 219, DoDD 3216.2 and AFI 40-402) for Organizational Change Associated with the Implementation of New Computer Software.

1.   Your request was based on the Code of Federal Regulations, title 32, part 219, section 101, paragraph (b) (2) Research activities that involve the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior unless: (i) Information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) Any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, or reputation.

2.   Your study qualifies for this exemption because you are not collecting sensitive data, which could reasonably damage the subjects' financial standing, employability, or reputation. Further, the demographic data you are collecting cannot realistically be expected to map a given response to a specific subject.

3.   This determination pertains only to the Federal, Department of Defense, and Air Force regulations that govern the use of human subjects in research. Further, if a subject's future response reasonably places them at risk of criminal or civil liability or is damaging to their financial standing, employability, or reputation, you are required to file an adverse event report with this office immediately.

11/26/2013

X

John Elshaw

JOHN J. ELSHAW, PH.D.
AFIT Research Reviewer

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Vita

Captain Stanton Brown graduated from Bigfork High School in Bigfork, MT. He was commissioned in 2005 with a Bachelor of Science degree in Mechanical Engineering from Montana State University. Captain Brown's experience as a Civil Engineer in the Air Force includes installation-level positions in environmental and base development programming at Eielson AFB, Alaska. He served as the readiness and emergency management flight commander at Kunsan AB, Republic of Korea. At Spangdahlem AB, Germany, Captain Brown's jobs included project management, asset management deputy flight chief, and squadron executive officer. He deployed three times in support of Operations ENDURING FREEDOM and ODYSSEY DAWN where he worked as the airfield development programmer, forward operating base detachment officer in charge, and team lead. He entered the Graduate School of Engineering and Management at the Air Force Institute of Technology in September 2012. Upon graduation, he will enter the Education with Industry program where he will learn facility asset management principles from a fortune 500 company in the private sector.

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14. ABSTRACT
A recent study assigned a grade of D+ on the nation's public infrastructure. Because of this poor asset condition, many organizations tend to respond to maintenance in a reactive mode; however, relying on corrective maintenance leads to increased maintenance costs due to unplanned downtime, increased labor costs, and inefficient use of personnel. To address this situation, asset management (AM) principles should be employed to transition organizations towards a proactive maintenance program. Unfortunately, it has been shown that two-thirds of the organizations failed to implement general change efforts. Therefore, an organizational change management framework should be followed to implement a change that will successfully transition organizations from reactive to proactive maintenance. This research effort focuses on building the framework for a change message to help Air Force decision-makers implement new Information Technology (IT) that addresses key AM principles such as asset condition and remaining service life. A Delphi study was utilized to elicit expert field knowledge on facility maintenance and respective IT. Results from the study, combined with literature guidance, helped formulate a change message to implement BUILDER™ to enable a proactive maintenance paradigm.

15. SUBJECT TERMS
organizational change management, BUILDER, asset management, facility maintenance, Delphi study

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U	U	U	UU	112	(937) 255-3636 x 7401 alfred.thal@afit.edu

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