



**DEFINING SUCCESS IN AIR FORCE INFRASTRUCTURE ASSET
MANAGEMENT THROUGH USE OF THE DELPHI TECHNIQUE**

THESIS

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AFIT-ENV-MS-18-M-220

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THESIS

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Degree of Master of Science in Engineering Management

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Captain, USAF

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Abstract

Asset Management has a history of policy mandates within the US Government dating back to 1990's. In order to accomplish these many directives, the Air Force Civil Engineer community has adopted a mindset and framework commonly referred to as Asset Management. Despite numerous references and guidance to establish Asset Management principles, the Air Force has not yet developed a clear and concise way to define or measure overarching success in Asset Management. This research effort focuses on closing the knowledge gap between issued policy and implementation. It examines Asset Management implementation efforts in other government agencies, private industries, and in various countries around the world. Combining this information with interviews from Subject Matter Experts at various levels of the Air Force Civil Engineering structure, this research identifies: current implementation limitations, key elements that constitute and promote success, barriers to success, military-unique opportunities for success, internal success identifiers, ways to promote continuous improvement, and the essential behaviors within Air Force Asset Management. Using this information and recommendations from the Air Force SMEs, suggestions are presented for measuring and incentivizing Asset Management success within an organization. Some of the major findings of this study were the need to develop both a clear definition of what asset management is and an official SAMP for the Air Force. Other findings of this research effort included: the importance of leadership buy-in; complete and accurate facility inventory; and understanding of asset management principles at all levels of the organization.

*This thesis is dedicated to God, who gave me the wisdom, passion, and ability to complete
this*

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Brendan J. Maestas

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I. Introduction

1.1 Problem Statement

According to the military appropriations bill for 2017, approximately one in four Department of Defense (DoD) facilities are rating as having poor or failing condition [1]. Interviews conducted by the Federal News Radio suggest that the percentage of failing facilities alone has increased from 7% of the Federal inventory in 2015, to 19% in 2016 [2]. United States Army Corps of Engineers classifies facilities with a ‘poor’ condition as having serious deterioration and being inadequate to meet its function, and facilities with a ‘failed’ condition as having general or complete failure causing the facility to no longer function [3]. As the agency charged with providing security at home and abroad, the DoD’s failing inventory is a major concern, with both the Government Accountability Office (GAO) and Congress calling for budget reform [1, 4]. Federal Government policy provides a budgetary goal for the DoD to meet 90% of its estimated facility sustainment requirements each year [4]. If the DoD creates an annual estimate for the amount of money needed to merely sustain its facilities in their current condition, then meeting 90% of that estimate will cause overall facility conditions to degrade overtime as the 10% of requirements are not met. However, from fiscal years 2009 to 2014, the DoD only met 80% of its sustainment requirements [4]. Thus, the alarming numbers of poor and failing facilities within the DoD should come as no surprise, as the DoD has been unable to meet the status quo of sustainment, much less improve the conditions of its already failing infrastructure. Further more, a GAO report found that while local military officials within

the DoD have tried to focus limited maintenance and repair resources on facilities that directly relate to the base's mission, these installations had numerous examples of facilities that negatively affected installation operations or created health and safety risks for base personnel [4]. Something must be done to improve facility conditions and make better use of limited funds, and asset management principles can help provide the solution.

1.2 Background of the Study

asset management is a relatively new field of study. Asset management originated out of maintenance management of the oil and gas industry in the 1980's [5]. Asset management has been gaining popularity in industry as companies seek to minimize lifecycle costs and maximize the operational longevity of their built infrastructure and equipment. The United States Air Force first entered into the realm of asset management through Executive Order 13327 [6]. This executive order, signed in February 2004 stated that "It is the policy of the United States to promote the efficient and economical use of Americas real property assets and to assure management accountability for implementing Federal real property management reforms." The executive order also directed that "executive branch departments and agencies shall recognize the importance of real property resources through increased management attention, the establishment of clear goals and objectives, improved policies and levels of accountability, and other appropriate action." 'Real property is a term used in the Federal Government, and is another name for built infrastructure and includes buildings, structures, utilities, improvements, and non-movable equipment essential to the operation of a facility [7]. The executive order defined 'Federal Real Property' as "any real property owned, leased, or otherwise managed by the Federal Government, both within and outside the United States, and improvements on federal lands."

As the catalyst for asset management, the executive order directed the appointment of a senior real property officer, and by extension, subordinate real property officers. Among

other things, these real property officers were charged with “prioritizing actions to be taken to improve the operational and financial management of the agency’s real property inventory” and “making life cycle cost estimations associated with the prioritized actions”. These tasks serve as the core of asset management ideologies.

1.3 Development of the Problem

Although the Air Force, as an agency of the Executive Branch, has been mandated to perform asset management for many years, many Air Force personnel don’t fully understand asset management. Within the Air Force community, asset management has been called a methodology and a process. For a brief period of time asset management was even its own flight within the Civil Engineer (CE) squadron organization. The flight, originally established in the CE transformation through Program Action Directive (PAD) 07-02 [8], was abolished just five years later in a second transformation via PAD 12-03 [9]. The justification for nixing the infant flight was that asset management principles should be used by everyone in an organization, and not just one group of people. Rather than increasing understanding, this re-transformation mostly succeeded in confusing understanding of the Air Force definition of asset management even further. The Air Force’s understanding of asset management has been further muddled by the fact that there is no overarching directive or guideline that establishes what asset management is, how it should be practiced, and what constitutes successful asset management.

All of these challenges work together to create a variety of disheartening futures for the base level civil engineer. The first potential future scenario is that a CE unit has been overwhelmed by all of the transformations and unclear guidance, and has resolved to disregard the conflicting information in order to do what they have always done. Another scenario is that a CE unit has a flawed understanding of asset management. This unit might be striving towards a goal that is not actually aligned with the Air Force’s strategic intent for asset management. Yet another CE squadron may truly grasp asset management and

be working fervently towards aligning their processes accordingly. The trouble is that this last theoretical CE unit, the one that actually understands asset management, will not have the policy backing or justification to support them. If the last CE unit runs into resistance or roadblocks, they will only have their personal beliefs and understanding to support their cause.

1.4 Purpose of the Study

The purpose of this research effort is to help achieve unity of thought and effort. By developing consensus on what Air Force asset management is, what asset management should look like, and what goals the Air Force should set, the researcher intends to align the Air Force CE community in effort and spirit. Once a strategic goal and vision for Air Force asset management has been established and agreed upon, then progress and innovation can flourish.

1.5 Significance of the Research

This research will help clear up confusion about the application of asset management in the Air Force. The research will provide opinions and recommendations that will extend the body of knowledge on Air Force asset management. While this research will not be the final word in asset management, it should serve as a turning point for future policy discussions on asset management.

1.6 Research Questions

The following questions serve as the focus of the research effort. By attempting to answer these questions the researcher will attempt to propose a unity of purpose and direction to the CE enterprise.

1. How should success in asset management be objectively defined and quantified?
2. What are the key components of success in asset management?

3. How can successful asset management principles benefit the CE community?
4. How can success in asset management be communicated and encouraged within the CE community?

1.7 Delimitations

The delimitations utilized by the researcher in this study were determined to develop an in-depth solution that was relevant to the Air Force CE community. In order to obtain useful and practical recommendations, the researcher only sought the opinions of experts in Air Force civil engineering. This focus did not allow the researcher to gain the views of individuals from other career fields within the Air Force, nor the opinions of individuals with similar functions in different branches of the military or government.

1.8 Assumptions

This study includes the following assumptions:

1. The selected experts have the necessary asset management experience to provide informed opinions.
2. The opinions of the selected experts are diverse enough to be representative of the rest of Air Force CE leadership.
3. The survey respondents shared the same understanding of the questions in the survey.
4. The interpretation of the data accurately reflects the perceptions of the respondents.

For this research effort, assumption number one is deemed reasonable because all of the selected experts are either daily practitioners or policy makers of asset management. Assumption number two is deemed reasonable because the experts that responded to the survey cover a wide variety of functional levels within the CE enterprise. Assumption number three is deemed to be reasonable because the respondent's answers to the survey

questions met the intent of the researcher who wrote the questions. Finally, assumption number four is deemed reasonable because the respondents were afforded the opportunity to provide open ended feedback of their perceptions with each round of the survey. Furthermore, assumption number four is deemed reasonable because the respondents were also afforded the opportunity to provide their perspectives on the aggregated data through certainty reporting in round two, and agreement reporting in round three.

1.9 Organization of the Study

This research study is presented in five chapters. Chapter 1 includes the background of the study, statement of the problem, purpose of the study, significance of the study, theoretical framework, research questions, delimitations, and the assumptions of the study. Chapter 2 presents a review of the literature, which includes asset management in private industry, asset management within the Air Force, and measurements for success. Chapter 3 describes the methodology used for this research study. It includes the selection of participants, instrumentation, data collection, and data analysis procedures. Chapter 4 presents the study's findings including demographic information, testing the research questions, and the results of the data analyses for the research questions. Chapter 5 provides a summary of the entire study, discussion of the findings, implications of the findings for theory and practice, recommendations for future research, and conclusions.

II. Literature Review

2.1 Introduction

The term *asset management* can be a relatively vague and nebulous term. It can be used to refer to a variety of loosely connected fields. The primary cause for the confusion is that many different industries value and subsequently manage a wide variety of assets. The term asset management itself is commonly used across the fields of finance, information technology, and infrastructure. Before any meaningful discussion can be had, it is imperative to clearly delineate which type of asset management is being discussed. According to Thompson Gale, financial asset management can be defined as “the activity of overseeing and making decisions regarding the investments of an individual, company, or other institution” [10]. Information technology, or enterprise asset management, “is the business of processing and enabling information systems that support management of an organizations assets, both physical assets, called ‘tangible’, and non-physical, ‘intangible’ assets” [11]. However, this thesis is not focused on either investment or enterprise asset management, but is instead focused specifically on infrastructure asset management. To that end, this chapter will:

1. Further define terms
2. Provide a historical background
3. Discuss the current status of asset management
4. Discuss different asset management applications
5. Explain several standard asset management decision making models
6. Explain the gaps in Department of Defense guidance

7. Provide support for the research effort
8. Explain the variables relevant to the research problem
9. Discuss any seminal studies and leading scholars
10. Discuss the useful theoretical constructs

2.2 Definition of Terms

- *Asset Management*: “involves the balancing of costs, opportunities and risks against the desired performance of assets, to achieve the organizational objectives” [12]. This paper will focus specifically on the management of real property assets belonging to the United States Air Force.
- *Real Property*: Lands, buildings, structures, utilities systems, improvements, and appurtenances thereto. Includes equipment attached to and made part of buildings and structures (such as heating systems) but not movable equipment (such as plant equipment). [13]
- *Civil Engineer*: In this research effort, civil engineers do not necessarily have to possess a Civil Engineer degree or license. Rather, civil engineers are members of the Air Force CE functional community, and are thus identified by their profession, not their personal expertise or education.
- *Success*: Beneficial and desired outcome.

2.3 Historical Background

2.3.1 Origins.

Infrastructure asset management is a relatively young field of study that is still in the process of maturing. The practices of asset management were originally borrowed from the financial sector and put into practice in the 1980's and 1990's by the North

Sea oil and gas industry [5]. Falling gas prices and several disasters forced the industry to develop the “Cost Reduction In the New Era” (CRINE) initiative [5]. The CRINE initiative forced a deep introspection that motivated benchmarking industry best practices, performance and budget accountability, and a healthy challenge to beat what had been the status quo [5]. One of the emergent asset management models, used by Shell Exploration & Production, was centered on the attributes and performance of the assets themselves, recognizing the input of operators and technicians, and acknowledged lifecycle of the asset from installation/construction to removal/demolition [5]. These common threads are still prevalent in the industry to this day.

As the asset management field emerged, many companies created positions for “asset managers” or even created an “asset management function” without fully grasping the performance or life-cycle focused aspects [5]. One of the key difficulties and points for confusion, is that the phrase “asset management” is often used ambiguously and without context for a purely business focus on maintenance actions rather than carrying the specific connotations discussed above [5]. This confusion and ambiguity of seemingly generic terms, when coupled with the multiple fields of asset management described previous, remains a key concern for companies or organizations seeking asset management maturity, as it can be difficult for the uninitiated to find information that is both relevant and useful to their field.

2.3.2 In US Government.

While many private companies have been involved in developing asset management in the United States, the Federal Government has also helped promote the field through a focus on managing the vast and diverse real property assets owned, maintained, and operated by the plethora of government agencies. However in almost every case, the government has implemented asset management principles in order to keep up with the asset management industry. Because asset management development has been led by private companies and

best practices, it can be difficult to find resources on the development of asset management that is not proprietary. As a result, this paper follows asset management development through published laws and regulations that make an effort to keep up with industry.

One of the first instances where the US Federal Government implemented asset management principles was to help combat the mounting national debt. Former President Bill Clinton charged then Vice President Al Gore, to lead a six month intensive study of the Federal Government with the primary goals of “make government work better and cost less” [14]. Vice President Gore submitted his team’s findings to President Clinton in September of 1993, which later became known as the ‘National Performance Review. One of the recommendations of the report was for the head of the General Services Administration (GSA) to “develop asset management principles to guide the Federal Government’s real property ownership enterprise” [14]. Among other things, the GSA is responsible for offering centralized procurement and acquisition for the Federal Government on everything from vehicles to office space [15]. In this capacity, the GSA led the first ‘Federal Asset Management Planning Group in 1994, which would ultimately develop and publish asset management goals and principles for the Federal Government [16].

The 1996 bulletin published by the Federal Asset Management Planning Group, came up with nine generic principles that would help fulfill Vice President Gore’s recommendation from the National Performance Review [16]. These nine goals were:

“Use What You Have First, Buy Only What You Need, Use Industry-Like Instruments of Agreement, Reinvestment is Essential, Income/Expenses Comparable to the Market, Maximize Use Among Agencies, Timely Disposal, Retain Proceeds From Disposal/Outleasing, and Professional Training” [16].

By including the principles of reinvestment and timely disposal, the Federal Asset Management Planning Group helped to promote a life-cycle view in government asset

management. The published bulletin was a valuable step in communicating asset management ideas within the Federal Government, but had two key limitations. The first limitation was that the bulletin only incorporated asset management on large scale assets such as buildings and tracts of land. The second limitation is that these principles, much like the recommendations of Vice President Gore, were not codified or mandated.

In order to address the concerns originally raised by the National Performance Review of 1993 and make asset management more prevalent within the Federal Government, President George Bush issued Executive Order (EO) 13327 in February of 2004. Through issuance of EO 13327, President Bush mandated that the “policy of the United States to promote the efficient and economical use of Americas real property assets and to assure management accountability” [6], could be mandatory for all 14 Executive Branch departments. Additionally, EO 13327 created the ‘Federal Real Property Council, a successor to the Federal Asset Management Planning Group, to be the governing body for federal real property asset management [6]. The council would fall under the Office of Management and Budget (OMB) and include newly created senior real property officers from each of the executive branch departments. These senior real property officers would be charged with developing and implementing an “agency asset management planning process” that met the requirements of the Federal Real Property Council [6]. Among the many stated responsibilities of the Federal Real Property Council, EO 13327 dictated that the council shall improve management of each agency’s real property inventory, and consider lifecycle costs when making decisions [6]. Lastly, EO 13327 tasked both the OMB and the GSA with developing initiatives that would adopt effective asset management techniques and best practices from the developing asset management industry [6]. Through issuance of EO 13327, President Bush helped to remove one of key the limitations of the Federal Asset Management Planning Group, by creating a mandates for what were previously recommendations or suggestions. Furthermore, as agencies began to take

accountability for their assets in accordance with the executive order, many were able to apply asset management principles beyond the real estate level.

Aided by the passing of the “Moving Ahead for Progress in the 21st Century Act” (MAP-21) in 2012, the Department of Transportation developed in-depth asset management principles that go well beyond EO 13327. MAP-21 requires individual states to create asset management plans that include performance measures and specific deadlines [17]. As a core requirement of each state’s asset management plan, MAP-21 emphasizes the need for “data collection, maintenance, and integration” that informs both risk and performance based asset management decisions to “improve or preserve the condition of the assets and the performance of the system” [17]. As a result, MAP-21 provides several significant developments for asset management within the Federal Government. First, by incorporating quantifiable performance measures and deadlines, MAP-21 helped to bring asset management to an actionable level. Secondly, the assimilation of both risk and performance based management help communicate how asset management can be used to inform decision making and prioritization processes. These developments allowed for a breadth of asset management applications not previously seen at the Federal level that also transcend the notion that asset management was only useful for saving money to keep up with industry best practices.

2.3.3 Asset Management Standardization.

As in the United States, asset management development has been led by private companies and diverse industries around the world. Similarly, the governments of many nations passed laws and regulations to keep up with the asset management industry. However, it was not until the development of Publicly Available Specification (PAS) 55, that any attempt at a concerted effort towards standardization was made. PAS 55 was developed under the leadership of Britain’s Institute of Asset Management (IAM) in 2004 in response to demands from industries that rely on physical assets for business and services

[18]. PAS 55 was a benchmark for the asset management industry because it provided a methodology for self assessment; encouraged professionalization through certification; encouraged continuous holistic improvement; outlined the organization and importance of strategy, objectives, and planning in asset management; and provided a standard framework and system for optimal and sustainable asset management [19]. The formalization and certification provided by PAS 55, allowed the asset management industry to delineate itself from others, and also provided a way to recognize competent companies and individuals. Secondly, PAS 55 underscored and explained the importance of coordination, commitment, competence, and clear vision from leadership [19]. Finally, PAS 55 emphasized not only the big picture management of real estate assets that prior US governmental regulations covered, but also knowledge about the conditions, performance, costs, and risks associated with all owned assets from “shop floor to the top floor” [20].

Although some consultancy firms and property owning companies included many of these best practices, it was not until the publishing of PAS 55, that these standards for asset management became widely known and available to the industry. After PAS 55 was released as a British standard in 2004, the IAM used British industry feedback to improve and enhance the original PAS, to release PAS 55:2008, in the year 2008 [20]. Following the re-release of PAS 55, the IAM began working the process of formalizing their work to be submitted to the International Organization for Standardization (ISO), which is the worldwide federations of international standards bodies. This effort came to fruition in 2014 after input and revision from organizations around the world, with the release of ISO(s) 55000, 55001, and 55002. ISO 55000 provided an overview of asset management principles and terminology [12]. ISO 55001 outlined the requirements for asset management systems [21]. ISO 55002 issued guidelines for the applications of ISO 55001 [22]. The ISO 55000 series notably emphasizes the importance of an internal ‘Strategic Asset Management Plan (SAMP) that aligns an organization’s asset management

policies with its individual corporate vision and strategy [12, 23]. Through the process of following creating a SAMP, an organization is able to tailor the generalized asset management systems described in the ISOs to the needs of the individual organization. The international standardization of asset management through ISO(s) 55000, 55001, and 55002 provides a globally recognized asset management vernacular which allows companies to benchmark best practices and become certified through an internationally recognized process. The United States Air Force does not currently adhere to the ISO 55000 series, and is not obligated to do so. However, the Air Force might be able to achieve great success by referencing the ISO, and building upon its principles.

2.4 Challenges to adopting asset management in the public sector

Unfortunately, challenges to public sector asset management are all too common and experienced all around the world [24]. In 2001, D.J. Vanier found that North American public sector asset managers struggled with data integration, standardization of asset management tools and models, information sharing, and a consistent lack of willingness to adopt asset management at all levels of the organization [25]. Looking at the nation of Indonesia, Muhammad Hanis found that the government lacked institutional and legal frameworks to support asset management policies, had complex jurisdiction issues, lacked necessary data, was constrained by limited resources, lacked efficiency, and was stifled by complex and poorly defined objectives [26]. In the nation of Ethiopia, Tendayi Gondo found that many municipal water and sanitation sectors across the country had not taken advantage of available technology, did not have any established asset management plans, lacked awareness of the condition of their assets, and lacked the financial resources and expertise to implement effective asset management. Recognizing many of the same challenges in 1997, Andrew Lemer advocated for the development of a comprehensive infrastructure management system [27]. They claimed that improvements to public infrastructure and the resolution of these challenges could be

realized through enhancing infrastructure reliability and efficiency; improving technology; increasing understanding of system behavior; improving design, construction, operation, and maintenance effectiveness; and increasing overall returns on public assets [27].

Much like the rest of the world, asset management is equally important and problematic in the United States because of the nation's routinely poor infrastructure. Since 1998, the American Society of Civil Engineers (ASCE) has rated the nation's public infrastructure with an overall D average [28]. In the most recent report for 2017, ASCE rated the overall infrastructure condition as a D+, with the transit sector being the worst with a D- grade, and the rail sector being the best with a B grade [28]. The report, which focuses on the specific challenges to public infrastructure, highlights sustained levels of poor funding, planning, and investments as the main causes for the nation's low grades [28]. In a separate report published in 2016, the ASCE estimated that the average household would lose over \$110,000 in disposable income from 2016 to 2040 due to infrastructure deficiencies [29]. Even worse, this loss of money is only from the failing infrastructure itself, and does not even consider the cost to fix it. The report goes one step further and estimates that the infrastructure investment gap would cause the nation as a whole to lost out on \$4 Trillion in Gross Domestic Product by 2025 [29]. Although neither the 2016 or 2017 ASCE report make explicit use of the phrase asset management, the 2017 report suggests that the solutions to America's failing infrastructure are strategy, sustained investment, leadership, thoughtful planning, and careful preparation for the future [28]. All of these solutions fall under areas that public infrastructure asset management plans and laws could directly address. In fact, the researcher would argue that the nation's failure to make appropriate investments, use condition forecasting, or consider the lifecycle of assets, is precisely why and how America's infrastructure is failing.

Despite the Executive Order 13327 mandate, many government agencies are still struggling to effectively implement asset management within their organizations [30]. In

fact, in 2013 Senator Thomas Carper saw the implementation challenges and introduced the ‘Asset Management Reform Act’ [30]. The act, which as of the writing of this thesis has not yet been passed, highlights many ongoing concerns about asset management that have been raised by the Government Accounting Office (GAO). First, the GAO found that federal agencies still do not have consistent, accurate or useful data about their real property assets [30]. Furthermore, without accurate or useful information, the ability to make the right decisions about property use, acquisition, or disposition; the GAO found that federal agencies were simply unable to meet the mandates of EO 13327 [30]. Through a series of random inspections in 2009 and 2010, the GAO found huge discrepancies and anomalies between what was being reported and what existed in the real world [30]. For example, a certain large facility that was reportedly 59% utilized turned out to actually be less than 10% utilized after inspection, while another smaller facility that was reported to be fully utilized had been vacant for over a year [30]. In addition, the report found that without uniform reporting of key data, the information that has been provided is of little value [30]. Finally, the GAO found that these anomalies and discrepancies were sometimes the result of agencies not understanding the guidance or caused by agencies choosing to disregard guidance all together [30].

2.5 Asset Management Successes

Although asset management has faced many challenges in the public sector, many private organizations have seen substantial growth and success after implementing asset management principles. The IAM provides the following as potential benefits of asset management: increased performance; reduced costs; increased risk management; increased confidence and credibility; sustainability; and increased stakeholder satisfaction [31]. Intercolombia SA, a private power utility company that provides electricity in South America, initiate a three year process to increase their asset management maturity and implementation [32]. Over those three years, Intercolombia SA was able to save \$5 million,

reduce risk and increase the reliability of their utilities to 99.99% [32]. Anglian Water, a water utility company focused on reducing their carbon footprint, was able to reduce their carbon capital by 45% overall, after five years of using asset management principles for investment and carbon management [33]. BIOFOS, a wastewater treatment utility company in Denmark, was able to simultaneously reduce their carbon footprint by 91% while producing over 35,000 megawatt-hours more energy over four years through implementing asset management investment systems [34]. Arcadis, an asset management consultancy firm, was able to help railroad companies realize up to 40% reduction in maintenance costs [35]. While these are great success stories, it is very possible that these examples are the exception rather than the norm. To identify the average scenario for companies implementing asset management, it will be helpful to look at some case studies.

The IAM conducted their own case study analysis of 100 organizations across the transportation/logistics, utilities, and oil/gas industries in four countries [36]. Their analysis found that the consistent areas for financial benefit were: better organizational alignment; improved processes; increased asset awareness and planning capability; and the ability to exploit value from lifecycle analyses [36]. Taking all of the case studies into account, the IAM suggested that improving asset management capability can deliver up to an 8% savings from the total cost of operations [36]. The results of this case study analysis are likely to provide an incentive for some organizations, but it will also be helpful to consider the difference between the best and worst asset management organizations in industry.

In 2014, the Aberdeen Group analyzed 149 businesses and ranked them according to their asset management performance and success [37]. Through the analysis process, the Aberdeen Group divided each business into three different maturity classes: “best-in-class” which was the top 20%, “industry average” which was made up of the middle 50%, and “laggard” which was made up of the bottom 30% of companies [37]. With regards to unscheduled asset downtime, the best-in-class companies averaged 3.5% downtime, the

industry average companies averaged 8.3% downtime, and the laggard group averaged 16.9% unscheduled downtime [37]. In the modern business environment, when time is money, unscheduled downtime can be incredibly costly. Speaking of costs, the Aberdeen Group found that best-in-class companies were able to achieve an average 13% reduction in maintenance costs, industry average companies achieved a 4% reduction in maintenance costs, and laggards actually experienced a 1% increase in maintenance costs when analyzed over the same period of time [37]. To conclude their findings, the Aberdeen Group listed the following steps to help companies move towards best-in-class status: use predictive analytics; close talent gaps; and combine sustainability and maintenance in asset management [37].

2.6 Asset Management Applied

Because of success stories like those mentioned in the previous section, asset management principles have been demonstrated to be useful in a wide variety of applications. Additionally, the ever increasing advancement of information technology has greatly aided the number and types of asset management applications. These applications may be diverse, but they all help inform decision makers on the condition, performance, and risk of their infrastructure assets.

2.6.1 Information Databases.

One of the ways that information technology has greatly aided the field of asset management, is with the development of different kinds of record keeping databases. The information in these databases can be stored on cloud computing networks or within an organization's intranet for easy access. There are many different types of databases made available to the asset management industry, so for ease of discussion, the databases will be divided into the following three broad categories: visual, condition-focused, and work-focused. As a caveat, the actual databases used by asset management professionals may cross categorical boundaries to maximize functionality.

The first database category that will be discussed is visual. Visual databases are used to help decision makers and analysts understand the physical environment and constraints that their assets exist in. One of the most popular visual databases in the construction and asset management industries is Building Information Modeling (BIM). BIM is based on the development of Computer Aided Design and is used in many different industries [38]. In fact, Zahra Pezeshki predicts that the wide applications and interdisciplinary nature of BIM will make it one of the “pillars of scientific research” from now into the future [39]. BIM typically provides three-dimensional data rich representations of the built and functional characteristics of a building or structure [39]. BIM can also incorporate four-dimensional and five-dimensional data, with the addition of a time and cost scale [38]. BIM files may have many different layers and can isolate views by system or location. Before construction, BIM designs can help a contractor and a customer communicate with greater fidelity than traditional schematics. During construction, BIM drawings can help builders understand the impact of proposed design changes. After construction, accurate BIM records can help a building owner plan modifications and renovations in a way that minimizes impact to existing systems. Some of the major benefits of BIM are: consistency; visualization; accurate estimates; and the ability to more accurately plan changes [38]. BIM is especially useful in asset management as a way to both communicate and understand the complicated interactions between infrastructure systems and their physical environment. Although the Federal Government listed BIM one of the three technologies that could dramatically improve data acquisition, maintenance, repair, and decision making [40], one of the major challenges to BIM implementation is the high cost and technical skill required, especially in pre-existing infrastructure [38]. An additional major challenge to wide adoption of BIM is that it is often not easily implemented or cost-efficient for many smaller scale projects such as restoration and modernization of pre-existing facilities.

Another common visual database type is Geographic Information Systems (GIS). GIS is typically a two-dimensional mapping application that can capture, manage, and even analyze all types of geographic data [41]. GIS is interactive, and like BIM, can filter maps by different types of information layers, within a single building floor plan or over a larger map. The possibilities for information that is associated to a geographic location are nearly endless [25]. An asset manager might use GIS to identify buildings that a property company owns within a diverse city, to highlight specific buildings within a campus by facility type or by occupant, or model different types of risk across a city [42]. The city of San Francisco has used GIS to map how funds are used in each of the city's 37 neighborhoods, allowing for better prioritization [43]. The Australian Government has used GIS to help build capacity for critical infrastructure protection via data gathering, modeling and visualization [44]. Andrew Lemer and JR Wright suggested that GIS is part of the first step of building an integrated infrastructure management system [27].

Condition-focused databases, sometimes referred to as engineered management systems are used by asset managers to track and record the health and status of infrastructure systems and equipment [25]. Asset managers can use condition-focused databases to track physical condition assessments and even to compute a Condition Index (CI), based on defects, assessments, or the age of an asset [25]. These CIs can then be used to describe risk of failure to decision makers or be used help plan and prioritize capital improvements. Condition-focused databases are also useful when analyzing the health of an asset over a period of time. Through analysis, an asset manager might discover that a particular piece of infrastructure has a CI that is decaying faster than normal, which might prompt further investigation and reinvestment.

Work-focused databases, also known as computerized maintenance management systems, facilitate an organization's ability to track work requests and task scheduling [25]. Work-focused systems can provide incredible value to organizations to ensure that

the appropriate personnel and resources are assigned to work requests, schedule preventive maintenance, and ensure that a customer's work requests are appropriately followed up. Asset managers can use work-focused databases in conjunction with maintenance personnel, to monitor the amount and type of maintenance that is performed on real property assets. Asset managers may also be able to analyze facilities or infrastructure systems that receive that the most work requests within a work-focused system to highlight issues that may require overhaul. Depending on how they are designed and implemented, work-focused databases can also help asset managers track materials, impact to mission, warranty information, costs, relevant manufacturer safety data sheets, and much more [40].

2.6.2 Mobile Collaboration Technologies.

Another application of recent technology that supports asset management is Mobile Collaboration Technologies (MCTs). The ability to connect mobile devices to the various types of asset management information databases has been a growing trend ever since the development of the personal data assistant and the mobile phone networks [45]. Mobile devices, is an intentionally broad category that includes but is not limited to lap-top computers, 'pocket' personal computers, tablets, and smaller devices like smart phones [46]. While mobile technologies are not yet fully mature [47], Christos Emmanouilidis listed them as having the ability to redefine conventional industrial asset management [48]. The key characteristics of MCTs are remote connection to databases, 24/7 connectivity, 2-way interaction with information, internet access, enhanced communication and collaboration, and data collection [45, 48, 49]. Asset managers can use MCTs to interface with visual, work-focused, and condition-focused databases for everything from job task management, remote communication, inventory control, and building inspection [45, 47–50]. Major challenges with MCTs include: the need to build interfaces across many platforms; processing power of the mobile device; screen sizes; interfaces; visualization; battery life; environmental conditions; the impact of device crashes on productivity; and

a susceptibility to malicious hacking [46, 50]. Despite these potential limitations, many organizations, including the U.S. military, have increased MCT usage for their unique capabilities, flexibility, and future potential [51].

2.6.3 Automation.

Advances in MCTs, sensor technology, and internet connectivity have also helped develop automatic sensors and controls for use in asset management [52]. These automatic controls and sensors, which were originally developed for processing plant operations [52], are useful because they allow asset managers to both remotely monitor and adjust equipment based on the environmental and organizational needs. When properly optimized, these sensors can connect with work-focused and condition-focused systems to detect various modes of failure and potentially generate work requests for maintenance personnel in the future [40, 53]. Many heating, ventilation, and air conditioning (HVAC) units can already be remotely monitored and controlled through environmental control systems. Energy usage and maintenance costs can also be minimized through appropriate automatic diagnostics and controls [54]. The pavement industry has also seen success from automatic controls, through vehicle mounted lasers and inertial sensors that automatically detect and record pavement distress [55]. The main challenges to automation in asset management are detection issues, controls, and consistency [52, 54]. Detection issues can provide difficulties because a system that does not minimize false positives or failed detection can cause more harm than good [54]. Controls provide challenges because while many remote sensors exist, diagnostics that don't result in action are useless [54]. Lastly, usage of automatic diagnostics are low in the industry because consistent solutions have not been achieved, despite many research efforts [52].

2.7 Predictive Analytics

As asset management continues to develop and grow with new technology, one area that has become increasingly important is predictive analytics. So much so that

Peter Sondegaard a Senior Vice President of a research firm, is quoted with saying that “Information is the oil of the 21st century, and analytics is the combustion engine” [56]. Furthermore the U.S. Federal Government’s “Committee on Business Strategies for Public Capital” identified condition prediction as one of the required elements within facilities asset management [57], and the ISO developed ISO 15686-2 for service life planning and prediction [22]. J.M. Braus identified performance prediction as absolutely necessary for sustainment and renewal planning [58], Gene Wolf highlighted that predictive preventive maintenance as the very strategy that helps asset managers move from a reactive to a proactive approach [37, 59], and Zahra Pezeshki claimed that condition forecasting should be the key element for decision making in service organizations [39]. The U.S. Army also stated that predictive analytics are useful for allowing planners to understand their future infrastructure and plan capital improvements [50]. Performance and condition prediction systems work by applying mathematical models, correlation, or artificial intelligence to known indicators such as age, wear, usage, historical data, and previous condition assessments [37, 59, 60]. Most predictive models follow the following four basic steps: identify potential predictor variables, diagnose interactions between variables, build the model, and perform statistical summaries [61]. Regardless of the method, these prediction models allow asset manager to predict deterioration of buildings, systems, and components; upcoming maintenance; degradations in service; and failures before they affect the bottom line or mission [37, 57, 59]. These predictions of condition as a function of time allow asset managers to preempt failure and plan maintenance or downtime at the most advantageous time and opportunity for the organization [37, 57]

Given the many types of infrastructure and equipment that asset managers are responsible for, it should be no surprise that there are many different types of predictive analytics. Some basic models use time as the key predictor, rather than any sort of predictor analysis [53]. Other models use a variety of statistical procedures and advanced

mathematical models to predict failure [62]. Still other models focus on how changes in the business or physical environment will affect the operations of their assets [39]. There are some situations where preliminary obsolescence or reduced levels of service are more important to predict than actual failure, so there are models that predict when an asset will no longer be economically efficient [63, 64]. For many organizations, the prediction models are used to determine not only the remaining service life but the effect that various types of corrective maintenance will have on extending that service life [65]. A final type of predictive analytics focuses takes the previous approach one step further, by implementing sensitivity analysis to evaluate a variety of ‘what if’ scenarios that could involve everything from reducing usage, to changing preventive maintenance plans [5].

Irrelevant of the variety in model types or applications, there has been a substantial amount of research and practical reports that affirm the usefulness of predictive analytics. D.J. Vanier required both lifecycle analysis and service-life prediction for asset managers to overcome challenges [25]. Andrew Lemer identified predictive and prescriptive analytics as necessary for any decision maker that seeks to assure effective infrastructure performance [27]. J.M. Braus recognized that predictive analytics allow an organization to forecast and anticipate the amount of sustainment resources that will be required in future years [58]. Ville Ojanen identified the value of predictive analytics by allowing an organization to optimize production processes to save both energy and money through decreased costs [66]. Jonathan Hagan emphasized that predictive and prescriptive analytics were key to providing necessary foresight into future service, performance, risk, and safety [67]. A model created by the Pacific Partners Consulting Group for evaluating the best method of recapitalization showed that a predictive maintenance model achieved the best or tied the best score in 10 of their 15 criteria [58]. ISO 55002 prescribes learning more about or using predictive analysis for any organization that is interested in continual improvement [12]. The U.S. Government recognized the value of predictive analytics, and recommended that

they be used for promoting transportation network progress into the 21st century [17]. In a 1999 primer, the Federal Highway Administration stated that predictive analytics allowed for the marked improvement in the communication of ideas and should be a part of any asset management system [68]. The United States Air Force saw the value of predictive life-cycle performance as a way to ensure that a unit's investment plans minimize risk and maximize return on investment [9]. Most of these affirmations follow the basic mindset that things are cheaper to repair or replace before they break, rather than after [37]. The 'Committee on Business Strategies for Public Capital underscored the importance of predictive analytics in predicting high maintenance needs and preventing the very serious consequences of failure for public infrastructure [57]. The ability to predict failures is especially important for critical infrastructure assets that are hard to monitor or hard to access, like sewer lines [61].

Taking the aforementioned affirmations further, Reid Paquin described the many different ways that the "best-in class" asset management organizations make use of predictive analytics. Paquin claims that predictive maintenance directly affects the bottom line because it improves quality, increases safety and affects everyone in the organization, from the inventory supervisor, the work planners, and the financial managers. Paquin further highlights that one of the primary goals of asset-intensive companies is to reduce unplanned asset downtime where an asset is not producing value [37]. By using predictive analytics, Paquin explains that decision makers have more time to plan and improvise effective strategies [37]. Paquin also mentions that a predictive maintenance approach helps relieve pressures by reducing costs, reducing the need for additional investment, optimizing labor requirements, and improving return on assets [37]. Finally, Paquin revealed that the ability to effectively predict maintenance has caused many best-in-class companies to outsource components of their maintenance plans to third parties that can perform those actions more cheaply [37].

Even with all of the benefits of predictive analytics, there are a number of limitations that hamper their usefulness in the asset management industry. First and foremost, the ability to predict deterioration and performance can be challenging because the factors that can affect facilities are diverse and complex [58]. Another limitation on forecasting ability is the quality of the collected data and the selection of appropriate predictors [61]. Furthermore, the quality of data and thus the quality of the forecasting ability, can be limited by the type of inspection that is performed [60]. The most detailed inspections, sometimes called “distress inspections” involve recording the number, size, and type of distresses on an asset in a condition-focused database. The least detailed inspections are sometimes called “direct inspections” are highly subjective, because they rely on the inspector’s opinion of whether the asset has a condition ranging from green, indicating a good condition and operation; through amber, indicating a warning of significant damage or degraded operations; to red, indicating serious damage or heavily degraded operations. This green, amber, and red rating system is commonly known as a ‘stoplight chart’, and implies that users should ‘go’ on green conditions, ‘slow down’ or take note of amber conditions, and ‘stop’ operations at red conditions. The experience of maintenance engineers or inspectors can still be very valuable when the model is imperfect or otherwise limited, but the importance of quality data must also be underscored [69]. The direct method is quicker, but far less scientific, and relies on the expertise of the inspector. When it comes collecting data for predictive maintenance, the distress method is best, while the direct method is severely limited [60]. Another limitation of the forecasting ability of predictive analytics is the difference between assets. It is likely that different pieces of equipment are made with different quality, are used differently, or are exposed to different environmental stresses. Since all of those differences are valid, for similar pieces of equipment, the differences between how various types of infrastructure degrade over time can be even greater [58]. On top of that, some forecasting and validation models are far

more sensitive to variability or extraneous data than others [61]. Beyond all of the types of variability it is important to also remember the famous quote from statistician George E.P. Box “All models are wrong, some are useful” [70]. In this way, Box stresses the implication that any predictive model will be imperfect, and so it is imperative that model builders also estimate and understand the ability of the model to actually detect failures [53]. Finally, Paquin explains that the largest challenge in implementing predictive analytics has not been the model itself, but actually the ability to overcome the cultural inertia required to switch from a reactive to a proactive maintenance approach [37]. However, Paquin also notes that organizations that have implemented predictive analytics have increased operational capacity by 20%, decreased maintenance costs by 25%, and even reduced spare part inventory by 20% [37].

In spite of the many inherent challenges, the future for predictive analytics is still very bright. In the future, organizations are hoping to be able to refine their models to the point that they can predict further, even up to 20 years in the future [62]. Others are seeking to integrate work-focused systems, predictive models, and automatic diagnostics into a single coherent system [53]. Still others are working to incorporate the latest advances in machine learning or artificial intelligence into the predictive models and condition-focused databases, so that the computers would actually be able to refine and improve the predictive models themselves through superior analytical abilities. [35, 59]. Regardless of the direction of future predictive analytic developments, it is very likely that more and more organizations will find ways to both leverage the benefits and minimize the limitations of forecasting.

2.8 Decision Making Models

One of the most important aspect of asset management is the ability to make informed decisions. In fact, the ISO 55000 series list the ability to make informed decisions as one of the core benefits of asset management and declares that the establishment of decision

making processes provide fundamental value to asset management and the organization [12]. However, the ISO also states that decision making processes must be aligned to the strategic goals and objectives of the organization [12]. As a result, the decision making paradigms of asset management should be individualized and unique to the organization. Some organizations need to know when to repair or replace equipment, while others are focused on saving the most money to protect the bottom line. Rather than trying to describe every single process, this research effort seeks to classify the decision making paradigms into a few basic categories. The first category, risk informed decision making (RIDM), is not an exact science but involves the integration of complex inputs, statistical models, and deterministic and probabilistic risk analyses [71]. With RIDM, an organization will determine what level of risk they can accept and then prioritize their investment and maintenance activities to ensure that they remain below a stated level of risk. The next category of decision making focuses on being able to maintain a stated minimum level of service (LoS) at all times. For a utility company, this might manifest itself in focusing infrastructure investment strategies to always achieve a certain level of reliability. For the military, focus on certain mission sets (like nuclear deterrence) would be designated as “no fail”. When failure is not an option, an organization will implement redundancy that is rarely cost effective, because the mission is more important than extra costs. One final broad category of decision making is multi-criteria decision-making (MCDM) models. MCDM models have been used for many years, and seek to optimize a complex set of criteria according to a predetermined scoring model [52]. One of the distinct advantages of MCDM models, is that the model allows organizations to assign numeric values to subjective inputs, such as reputation or comfort, into decision making [52].

2.9 Maintenance Strategies

Maintenance strategies, much like decision making models, are usually tailored to the specific needs of an organization. This research seeks to discuss just a few of the

most common types of maintenance strategies. One type of maintenance strategy that borrows elements from both LoS and RIDM, is condition based maintenance (CBM). CBM can be used with or without predictive analytics, and uses certain condition thresholds to trigger maintenance activities [72]. CBM is a proactive maintenance approach that functions under the understanding that the optimal time to repair or replace an asset may be sometime after peak functionality but before complete failure. An organization may decide what conditions are used to trigger maintenance activities based on industry standards or based on acceptable LoS. CBM also recognizes that lower condition levels lead to increased risk in assets. Another popular maintenance strategy that focuses on conditions, is condition based operation (CBO). Whereas CBM uses a degraded condition to trigger a maintenance action, CBO uses the condition of an asset to dictate how an asset is used [72]. CBO is especially prevalent in industries like wind power generation, where assets may be exceptionally expensive to repair, or where unscheduled maintenance is far more expensive than scheduled maintenance [72]. In these situations, it may be more advantageous for an organization to throttle the use of an asset so that it is able to survive until the next scheduled maintenance. One final maintenance strategy that an organization might choose to implement is opportunistic maintenance. Opportunistic maintenance recognizes that maintenance activities often require shutting down systems like power or water that can significantly impact the operations of the organization. As a result, opportunistic maintenance seeks to minimize down time to operations and may choose to schedule less critical preventive maintenance during an outage that is caused by a system failure, corrective maintenance, or unrelated shut-downs [73]. Although the total amount of down time may exceed the minimum amount of time necessary to fix a specific problem, opportunistic maintenance optimizes maintenance to minimize the number of times that operations is affected by outages [73].

2.10 Example Asset Management Models

As has been previously stated, although asset management has a few core philosophies, implementation can vary widely based on the specific strategic goals of the organization. To demonstrate how implementation can differ, this paper will discuss two very different organizations that utilize asset management: The U.S. Federal Highway Administration and the U.S. Air Force. These organizations provide an interesting comparison, because both fall under the Federal Government and thus, are not driven by profit. Secondly, both of these organizations are very large, and have geographic and organizational diversity across their respective enterprises.

The key tenet of the Federal Highway Administration (FHA) model is decentralization. The FHA is a subdivision of the Federal Department of Transportation (DoT) and is responsible for providing oversight and guidance to the 50 state DoTs [74]. In 2002, the American Association of State Highway and Transportation Officials (AASHTO) partnered with the FHA to create the AASHTO Transportation Asset Management (TAM) Guide [64]. This TAM guide was significantly updated and re-released along with a ‘Focus on Implementation Guide’ following the passing of the MAP-21 act [17, 64]. The TAM recognizes that there is no “one size fits all” solution for every state DoT [64]. Instead, both the TAM guide and its implementation guide recognize the diversity of organizations based on maturity, knowledge, experience, political and physical environment, resources, asset criticality, risk management, supported populations, and forecasting ability [64]. Furthermore, the TAM guides also appreciate the rapidly changing and developing technological and political environments in which the state DoTs can find themselves [64]. To help the state DoTs, the TAM guides advocate a 14 step process for organizations to develop their own “Transportation Asset Management Plan (TAMP) that is tailored to each organization’s unique personality, circumstances, needs, and environment. This process is made up of the following steps:

“Set agency goals and objectives, Self-assessment and gap analysis, Define scope of TAM in the agency, Develop the change strategy, Integrate TAM into agency culture, Integrate TAM into business process, Establish asset management roles, Performance management standards, Develop the TAMP, Service Planning, Lifecycle management, TAM integration, Information systems, and Data collection and management” [64].

Throughout the process the TAM guides focus on three core principles: understanding asset value, achieving lifecycle cost efficiencies, and asset stewardship [64]. Another feature of the TAM guides is the TAM maturity scale. Self-assessing an agency’s asset management maturity comes in step two of the process, and is considered part of the gap analysis [64]. The TAM guides instruct agencies to determine whether they are “Initial, Awakening, Structured, Proficient, or Best Practice” [64]. While not nearly as detailed as the ‘Self Assessment Methodology developed by the IAM for PAS 55 [18], the TAM maturity assessment allows agencies to set a baseline and understand how they can improve once an agency’s goals and objectives have been established in step one of the process. One of the serious shortfalls of this type of asset management model is that it requires expertise, time, and significant effort for every state DoT organization.

The U.S. Air Force’s most recent Activity Management Plan (AMP) takes a far more centralized approach than the TAM from the FHA and AASHTO. The Air Force uses the AMP construct to apply asset management principles to their inventory. The primary purpose of AMPs is to manage activity processes, as well as to identify and prioritize investment needs [75]. The Air Force is in the continuous process of creating and refining ‘Air Force Common Output Level Standards (AFCOLS), that will help dictate metrics for the AMPs. The AMP model is meant to optimize and prioritize investments, identify problems in action plans, incorporate levels of service, articulate risk, allocate funds, and provide financial transparency [75]. AMPs are analyzed at the base level to

become ‘Base AMPs (BAMPs) [75]. Each BAMP is rolled up to their respective major command (MAJCOM) in order to be consolidated into a MAJCOM AMP (MAMP) [75]. A MAJCOM functions as a higher headquarters for several bases aligned under similar mission sets. Each MAMP is subsequently consolidated into an Air Force enterprise level view as an Air Force AMP (AFAMP) [75]. Then the AFAMP is used to build the ‘Integrated Priority List (IPL) that is used to plan and execute construction, sustainment, restoration, and modernization projects. Once budget constraints are applied, the IPL will indicate which projects will and will not be funded. In this way, an investment need that has been identified at the base level is reprioritized at the MAJCOM and Air Force levels in the corresponding MAMPs and AFAMP [75]. Each AMP is made up of four corresponding sub-AMPs: facilities; utilities; airfield and transportation networks; and natural infrastructure and real estate [75]. Each sub-AMP has a manager for each AMP level (base, MAJCOM, and Air Force) who is responsible for identifying and prioritizing needs within their functional focus [75]. This division and organization can allow the Air Force to achieve centralized oversight of worldwide assets, so long as appropriate Subject Matter Experts (SMEs) are in charge of the sub-AMPS. One of the shortfalls of the Air Force asset management model, is that it does not define or consider asset management maturity or knowledge at the various levels of the organization. In this way, organizations might be adhering to policies and procedures inspired by asset management principles, without understanding those principles themselves. The consequence of this is a lack of organizational alignment that hampers full asset management integration across the Air Force.

2.11 Support for the Research

The need for research on defining and measuring success in Air Force asset management is threefold. First and foremost, as a government agency, the Air Force is plagued by many of the same woes experienced the world over when it comes to

implementing public infrastructure asset management. Secondly, because the Department of Defense falls under the Executive Branch, the Air Force is subject to a number of laws and regulations that mandate asset management, while simultaneously being a part of the issues outlined by Senator Carper and the GAO [30] in the drafted Asset Management Reform Act. Thirdly, as suggested in the previous section, the Air Force's current asset management system does not provide a cohesive or comprehensive definition for asset management, struggles to provide organizational alignment and strategic vision, and does not provide overarching goals and objectives for asset management across the organization. Although under no legal obligation to follow the ISO 55000 series, the Air Force could certainly benefit from the development of a SAMP. The efforts to define and measure success in Air Force asset management as conducted by this research effort, could provide the foundation for both this potential SAMP and the AFAMP process at large. Ultimately, this research could close the gap in public infrastructure asset management knowledge, that would help inform and lead other Executive Branch agencies beyond macro real estate management toward effective asset management implementation at every level of their organizations.

2.12 Seminal Studies Widely Cited

The field of asset management does not have any significant or widely cited seminal studies. This fact is a result of a confluence of causes. First, the field of asset management is still emerging and developing. Second, asset management is a field that is being driven and developed by private industry, not academia. Lastly, many companies make their livelihoods off of asset management consulting, and are therefore not incentivized to publish their findings or best practices. The closest thing to a seminal or widely cited study in the field of asset management would be ISOs 55000, 55001, and 55002, which are the international standards for implementing asset management within an organization.

2.13 Leading Scholars

Although not a single specific scholar, the IAM is certainly a leader in the development of asset management. As previously stated, the IAM is responsible for authoring PAS 55, which became ISOs 55000, 55001, and 55002.

2.14 Summary

This chapter highlighted the development of asset management, successes that can be achieved through asset management, applications of asset management, how predictive analytics are used by the asset management industry, asset management decision making models, typical maintenance strategies, models of asset management from the Federal Highway Administration and the Air Force, support for the research, seminal studies, and leading scholars. The efforts of this research will be focused on informing Air Force leaders and future asset management policy. Based on their meta-analysis, Gene Rowe and George Wright found that the Delphi Technique was most used for “goal selection, policy invention, alternative rating, and likelihood judgment” [76]. This research follows this recommendation and the Delphi Technique for both goal selection and potential policy invention.

III. Methodology

3.1 Introduction

The primary goal of this research is to examine questions that relate to defining and measuring success within the context of Air Force asset management, as stated in Chapter 1. The Delphi technique is used for collecting data, with three rounds of questionnaires required. The methodology employed is presented in this chapter. The chapter is organized into five sections: (a) overview of the Delphi technique, (b) selection of participants, (c) instrumentation, (d) data collection, and (e) data analysis.

3.2 Delphi Technique

3.2.1 Delphi Technique Overview.

The Delphi technique was developed by the RAND corporation in the 1950s and is particularly useful for gathering and refining group opinion [77]. Per RAND's descriptions, the Delphi technique must have three key features: anonymity, iterative feedback loop, and a statistical summary of the group opinion [77]. Anonymity is self-explanatory, and is used to ensure that every opinion is accounted for equally [76–78]. Additionally, by having participants remain anonymous from each other, the researcher prevents strong opinions or personalities from exerting undue influence on others. An iterative feedback loop is characterized by a systematic process, done repeatedly, while ensuring that feedback is carefully controlled between rounds [77], and allows the anonymous responses to be built upon by the group while still remaining anonymous. Lastly, the statistical summary of group opinion ensures that the data is appropriately and mathematically aggregated in a way that reduces bias, erroneous commentary, and social pressures [77]. While several commentators admit that the Delphi technique needs more work to establish comparative

legitimacy [76, 78], the Delphi technique is still considered to “be a better procedure for producing accurate judgments than standard groups” [78].

3.2.2 Delphi Technique Problems and Critiques.

Based on the results of their meta analysis, Gene Rowe and George Wright indicated that the three main issues across the 27 published Delphi technique studies that they analyzed: 1. Subjects or researches did not recognize the significance of the task at hand and therefore did not appropriately record actual conditions. 2. Choosing subjects that were not representative of the true population. 3. Use of summary statistics while ignoring individual analysis [76]. To combat the first issue, respondents in this study were provided with both an explanation of the research goals and a brief background on why the study was needed. The explanation and background that the researcher provided to the respondents is shown below:

“The purpose of this study is to research and define success for Air Force civil engineers within the context of asset management. The goal of this research is to produce a shared understanding of asset management success, and a set of tangible goals that CE units can strive for. This research will be conducted via the Delphi technique, in which the researcher contacts subject matter experts to help develop a consensus of opinion. The researchers will send out subsequent questionnaires to develop and refine expert opinions. At the conclusion of this research effort the researchers intend to publish and present the results, as well as brief those results to CE leaders in order to potentially affect a change in Air Force policy.”

Rowe and Wright found that many of the Delphi technique studies they analyzed were flawed because their subjects were homogeneous or inexperienced [76]. Peter Ayton and others took this critique one step further with the explanation that inexperienced subjects do not have the necessary skills that experts attain through relevant experience, education

and training. [78]. This study resolves this issue by including a set of diverse Subject Matter Experts (SMEs) with a variety of experience with Air Force asset management. Lastly, in order to resolve the issues regarding group averages, this research will ensure that the commentary and results from all participants are both statistically summarized and individually considered for the analysis. Where appropriate, the research methods use mathematical tools to explain and analyze the data. Additionally, the researcher ensures that respondents are provided the opportunity to explain their numerical responses as needed. This commentary is included with the data for the reader.

One of the main critiques of the Delphi technique is that while it helps reduce the influence of strong willed personalities, the process does not allow for the positive synergistic performance effects that can be seen from cooperative brainstorming or collaboration efforts [78]. While a valid concern in many circumstances, this critique is less applicable to this particular research study because it is concerned with how particular individuals understand strategic policy. Furthermore, the benefits from collaboration can still be achieved in this study through the iterative feedback mechanism where anonymous opinions are shared with the group through multiple Delphi technique rounds.

3.3 Selection of Participants

3.3.1 Process.

In order to help create policy and drive a shared understanding, this study relies on the opinions and experiences of Subject Matter Experts (SMEs). The researcher and research sponsors originally identified twenty experts as SMEs in the areas of Air Force asset management application, implementation, or policy. All SMEs are currently employed by the United States Air Force as Active Duty members or Government Service (GS) civilians, to ensure that their expertise was relevant to the most current policies and state of the Air Force. Although no formal criteria were established to be considered as a SME, the

researcher selected individuals that worked within the Air Force CE community who were well versed in asset management policy and practice.

All twenty SMEs were emailed during the first round of the Delphi technique study and asked to participate. Of the twenty SMEs, only nine individuals provided responses to round one, giving a response rate of 45%. A meta analysis of survey response rates indicate that the average response rate for emailed surveys is about 33% with a standard deviation of 22% [79]. Thus, the response rate of 45% for this research is better than average, but still within normal bounds. The second round of the Delphi technique questionnaire was only emailed to the the nine SMEs that responded to the first round. Of those nine participants, seven SMEs provided responses for the second round of questions. The third round of the Delphi technique questionnaire was emailed to the nine SMEs that responded to the first round. Of those nine, seven SMEs provided responses for the third round of questions. Of the original nine respondents to round one, six individuals responded to both rounds two and 3, while one individual responded to round two but not round three, and another individual responded to round three but not round two.

3.3.2 Demographics.

The following figures show the basic demographic information for the nine SMEs that responded during the first round of the Delphi technique study. Even though females were included in original twenty SMEs, only male participants provided feedback. The researcher does not perceive this to be an issue, as gender does not have a direct influence on the topics at hand. Ethnicity, race, and age information was not collected, because these criteria are not deemed to be relevant to the study at hand. Figure 3.1 shows the different functional levels of the respondents and suggests a breadth and diversity of functional experience.

Under a normal Air Force CE organization, a squadron is responsible for the operations and maintenance of a single base's real property. The squadron can be said

to function at the tactical or bottom level of asset management, where data is collected and base-wide decisions are made. Multiple squadrons are organized into a group, and multiple groups are organized into a wing. While some installations have CE Groups (a CE unit that is too large to be a CE squadron), most bases do not have civil engineers or infrastructure asset managers outside of the squadron. There are some civil engineers with asset management expertise at the major command (MAJCOM) level, that are responsible for oversight of several different bases. The MAJCOM can be said to function at the operational level of asset management, where data from multiple bases is aggregated. At the MAJCOM level, aggregated data can be used to make decisions that influence an entire operational mission set such as long range missiles, or cargo aircraft. Above MAJCOMs, in the chain of command, is Headquarters Air Force (HAF). HAF employs civil engineers that are responsible for oversight of the entire Air Force enterprise. The Secretary of the Air Force (SAF) is the head of the Department of the Air Force. Civil engineers that work at HAF and SAF levels can be said to function at the strategic level of asset management, where decisions are made from data aggregated across the entire Air Force. The Air Force CE Center (AFCEC) is not in the direct reporting chain of command for the squadron, MAJCOM, or HAF. AFCEC is nonetheless responsible for leading, training, and providing solutions for civil engineers across the Air Force. AFCEC can be said to function at the institutional level of asset management, where guidance and directives from the strategic level are turned into policies and practices for the operational and tactical levels. The Air Force Institute of Technology (AFIT) is an educational institution that can provide continuing education and advanced academic degrees to civil engineers.

Figure 3.2 shows the different ranks of the respondents. Different Air Force officer career fields can have different career paths and opportunities for leadership. For the purpose of this study, descriptions of typical experience at different ranks will refer to CE officers only. A Captain (O-3) is an officer that typically has between 4 and 10 years

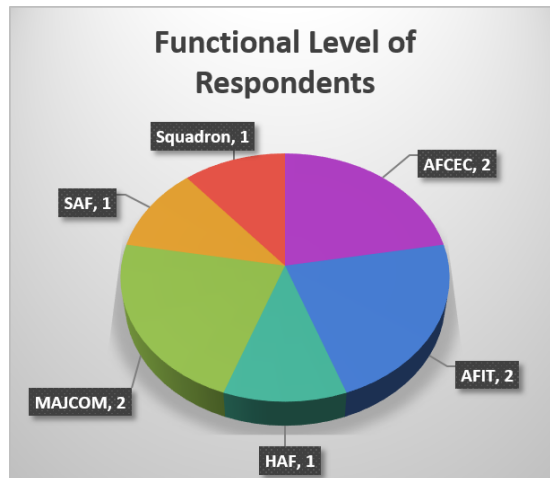


Figure 3.1: Functional Level of Survey Respondents

of experience in the career field and has often had opportunities for lower level leadership within the squadron. A Major (O-4) is an officer that typically has between 10 and 16 years of experience in the career field and has usually had multiple opportunities for leadership within the squadron. A Lieutenant Colonel (O-5) is an officer that typically has between 16 and 22 years of experience in the career field, and has had multiple opportunities for leadership at and above the squadron level. A Colonel (O-6) is an officer that typically has 22 or more years of experience in the career field, and may have had leadership opportunities at the operational, strategic, or institutional levels. Positions for civilian leadership within the Air Force CE career field are part of the Government Service (GS) ranking system. GS ranks are awarded by position, and civilians can be direct hired to a GS position without prior experience with the Air Force. As a result, it is difficult to summarize typical GS experience or progression. A GS-12 is civilian that is roughly equivalent to an O-3, and typically works at the squadron level. A GS-14 is a civilian that is roughly equivalent to an O-5, and typically works above the squadron level. This diversity of rank, when coupled with the diversity in functional level helps ensure that this research includes a variety of relevant experience.

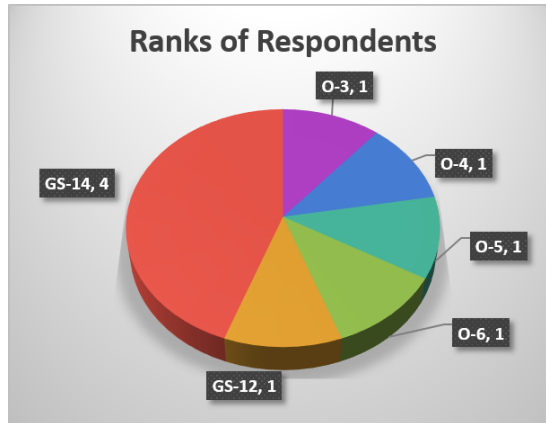


Figure 3.2: Ranks of Survey Respondents

3.3.3 *Representativeness of Participants.*

This research achieves representativeness across the Air Force CE enterprise by including input from SMEs at a variety of ranks and functional levels. Since asset management is still maturing within the Air Force CE community, the researcher did not feel that it was advisable to widely solicit opinions from non-experts or non-civil engineers. Additionally, since one of the purposes of this research effort is to help establish consistent policy guidance, the policy inputs should reflect the thoughts and opinions of those who are most intimately involved with asset management. Air Force members with less experience may differ in their understanding, but they are unlikely to have a better understanding than the experts.

Although this research is based on military and civilian responses from the tactical, operational, strategic, and institutional levels of asset management, there are two groups absent from this analysis. The first missing group from the study are General Officers (GOs) and Senior Executive Service (SES) employees. CE GOs and SES employees, while few and far between, are responsible for higher leadership and policy creation. Perspectives from both would be beneficial to this research effort, but no current or retired GOs responded to the survey, and no SES employees were asked to participate (an unintentional oversight

from the researcher). The second missing group from the study are enlisted. With respect to asset management, enlisted members of the CE community are typically responsible for hands on data collection, and the daily operation and maintenance of real property assets. Perspectives from enlisted could be beneficial to this research effort, but no enlisted personnel responded to the survey.

3.4 Instrumentation

This section will cover the methods for administering the Delphi technique responses.

The goal of round one of the study was to solicit individual suggestions and responses to the questions. As a result, the questions were developed by the researcher and designed to provide information related to the research questions. The questionnaire was administered through 19 open ended questions contained within an Adobe portable document file.

The goal of round two was to identify agreement and rankings for the responses that were provided as feedback to the round one questionnaire. As a result, the participants were provided nine questions from round one, and asked to rank the importance of each of the themes that were identified in the previous round. For example, themes that were identified in successful asset management were: adequate resources, adhering to established policies & strategies, focusing on the long-term lifecycle of assets, leadership buy-in, and making the right investments. In order to avoid leading questions, themes were sorted alphabetically when provided to the participants for ranking. After each question that asked for rankings, the participants were provided with the opportunity to rate the confidence in their rankings. Three open ended questions were also asked to achieve opinions and suggestions about responses to round one questions. The remaining seven questions from round one that were not addressed in round two, provided useful qualitative data that did not need additional clarification from subsequent rounds.

The goal of round three was to assess agreement on the rankings from round two. To prepare for round three, the individual rankings from round two were aggregated. In round three, the nine participants from round one were asked to rate their level of agreement with the aggregate ranking of themes, where a score of 1 indicated strong disagreement, a score of 2 indicated disagreement, a score of 3 indicated neither agreement or disagreement, a score of 4 indicated agreement, and a score of 5 indicated strong agreement. Participants were also asked to provide feedback whenever they disagreed with the aggregated rankings.

3.5 Data Collection

The round one and round two questionnaires were distributed via email, and sent to each SME through the blind carbon copy (bcc) email feature, in order to achieve and maintain participant anonymity. The email text for the round one questionnaire is shown in Appendix A.

Responses for both rounds were numbered in the order that they were received. Thus, “response #3” for round one will be the third person to respond to round one of the questionnaire. “response #3” for round two will similarly be the third person to respond to round two of the questionnaire, but will not necessarily be the same person from “response #3” for round one. This is done to further ensure that anonymity of the participants is maintained throughout the Delphi technique study. Anonymity between rounds was also kept because the participants were asked to perform different tasks in each round of the survey, and the researcher did not feel it was necessary to compare or comment on an individual’s responses across each round of the survey.

3.6 Data Analysis

3.6.1 Round One.

After all responses to the round one questionnaire were received, the data was consolidated for each question. Once the data was consolidated, the researcher looked

for consistent themes across the responses for each question. Similar or recurring themes were highlighted in the same color for ease of recognition. To be considered as a theme to be highlighted, a topic would need to be highlighted or emphasized by more than one respondent. After themes for each question were highlighted, they were counted and analyzed in preparation for the round two questionnaire. Based on this analysis, twelve responses from round one were chosen for further clarification in round two.

3.6.2 Round Two.

As responses to the round two questionnaire were received, the researcher consolidated the seven responses into a Microsoft Excel spreadsheet. The researcher then used the conditional formatting capability within Microsoft Excel to color the rankings in the spreadsheet, in order. This is done to aid the researcher, by making the data easier to analyze visually. After all responses were received, the numerical rankings for each theme were summed. The researcher again used conditional formatting to color the summed rankings in the spreadsheet, in order. In the event that two different themes within the same question had the same sum of rankings across the seven responses, the researcher rated the theme with a lower standard of deviation as more important. Next, the data were summarized in graphs. Finally, the researcher used the ‘corrplots package in the ‘RConsole program to determine pairwise correlations between respondents across the round two questionnaire and also by individual questions. The corrplots package treated each respondent’s rankings as a string of numbers and then determined the correlation between each respondent’s rankings and each other respondent’s rankings. Respondents with similar rankings would therefore have a greater positive correlation (closer to positive 1.0) between their rankings. Consequently, respondents with opposing rankings would have a greater negative correlation (closer to negative 1.0) between their rankings. Lastly, respondents with rankings that were unrelated would have correlations close to zero.

3.6.3 Round Three.

Once responses to the round three questionnaire were collected, the researcher recorded them in a Microsoft Excel spreadsheet. The researcher then took an average of the levels of agreement for each provided ranking to determine overall agreement for the aggregated ranking. The corrplots package was used in round three to determine the correlation of levels of agreement between each respondent.

3.7 Summary

By adhering to the methodology described above, the researcher ensures that each of the three requirements for a Delphi technique as outlined by Dalkey (anonymity, iterative feedback loop, and a statistical summary of the group opinion [77]) are upheld.

IV. Results and Discussion

This chapter is organized in such a way to demonstrate the progression from the research questions through each of the three rounds of the Delphi technique questionnaire. This chapter will not only include the responses to each of the questionnaire rounds, but also show how the responses from one round were used to develop the questions to the following questionnaire.

4.1 From Research Questions to Round One

Each question that was asked in round one of the Delphi questionnaire was developed in order to either answer one of the research questions, establish context, or confirm the hypothesis that there is a problem in Air Force asset management. Please note that some questions were developed to serve more than one purpose. In such cases, a single round one question will fall under more than one category. For a complete list of questions, refer to Appendix B.

4.2 Round One Results

The round one results section compiles each of the responses to the round one survey by question. The numbers below each question indicate the respondent that provided the response. This numerical respondent identifier remains consistent throughout the round one responses. The responses to each question have been highlighted in different colors to show consistent themes within the responses to a single question, but are not consistent between different questions. For example, a green highlight in question 1 does not necessarily represent the same theme as a green highlight in question 2.

4.2.1 Round One, Question 1.

From the responses to ‘What does asset management mean to you?’, the researcher identified the following themes: value/cost focus, an intentional process, lifecycle mindset,

performance focus, risk focus, data/condition focus. In the highlights, the value/cost focus is identified in green, the intentional process is identified in blue, the lifecycle mindset is identified in yellow, the performance focus is identified in pink, the risk focus is identified in red, and the data/condition focus is identified in purple. The responses and themes are shown in Figure 4.1.

1. What does Asset Management mean to you?

1. A lifecycle cost view of assets influencing initial investment and enduring sustainment decisions based on desired performance at the most effective cost driven by risks accepted for those costs
2. Scheduled, prioritized facility maintenance and repair with an emphasis on maintaining the service-life of a facility or infrastructure.
3. Asset management helps organizations better achieve organizational objectives while realizing greater value from their assets.
4. It is a deliberate, documented approach to maximize the value and effectiveness of a group of assets to meet organizational goals through application of labor and investments to sustain/repair/dispose of these assets through their lifecycle.
5. Asset Management means taking the available facility data and conditions and combine it with available assets and determine the best utilization of available assets. Assets include money and manpower.
6. 100% asset inventory with age, condition, repair/replacement cost, expected life, etc.
7. To me, AM is the coordinated process and philosophy that an organization undertakes to recognize and extract value from its assets. Value can be tangible or intangible, and assets can be anything that does or has the potential to provide value to that organization
8. Investing the right amount of resources in the right assets at the right time.
9. Asset management to me is managing the life cycle of an asset at an established performance level at the lowest cost while factoring in risk to mission and fiscal constraints

Figure 4.1: Round One, Question 1 Results

4.2.2 Round One, Question 2.

From the responses to ‘What are the key elements that make up asset management?’, the researcher identified the following themes: inventory, specific process, enterprise/organizational alignment, resource focus, planning/decision making, condition ratings, and risk. In the highlights, inventory is identified in yellow, specific process is identified in purple, enterprise/organizational alignment is identified in red, resource focus is identified in orange,

planning/decision making is identified in pink, condition rating is identified in green, and risk is identified in gray. The responses and themes are shown in Figure 4.2.

2. What are the key elements that make up Asset Management?

1. **Inventory** of what you have, **condition assessment** of those assets, **enterprise guidelines** for **performance**, e.g. all roofs should last xx-years, and then an **integrated management process** ensuring investment **decisions** target that **performance** goal
2. **Prioritization** of facilities and maintenance items, defined desired service life, **measurable performance indicators**, adequate **resources** to meet facility **investment** requirements.
3. Six of them: 1) **Strategic Planning**; 2) **Organization and People**; 3) **Decision Making**; 4) Life Cycle Mngt; 5) **Knowledge Mngt**; 6) **Risk and Review**
4. An **asset inventory**, **documented processes**, a clear understanding of requirements that the assets fulfill, **methods to understand how well those assets are performing or meeting the needs of the organization**, a governance structure that sets **policies** and **organizational goals**.
5. Manpower to gather and **analyze data/condition assessments**. Money to fix or replace problematic system/infrastructure. Plans to backup **methodologies** of utilizing **resources**.
6. **Complete data**, **accurate data**, and **maintained data**.
7. First and foremost: **an asset inventory**. Next, an understanding of the lifecycle of that inventory (both designed and actual). A definition of **value** is also essential (tangible or intangible). Finally, this whole thing is useless without an understanding of the **organization's purpose**, **mission and vision at all levels** (strategic, operational, and tactical).
8. **Risk**, **priorities** and the **decision making model** that integrates those things
9. Key elements are knowing what you have (**inventory**), its **condition**, **performance requirements**, **value/risks** to **mission**, & **life expectancy**

Figure 4.2: Round One, Question 2 Results

4.2.3 Round One, Question 3.

From the responses to ‘What aspects of asset management help an organization succeed the most?’, the researcher identified the following themes: leadership, resources, following policy, and long term/lifecycle focus. In the highlights, leadership is identified in purple, resources are identified in blue, following policy is identified in pink, and long term/lifecycle focus is identified in yellow. The responses and themes are shown in Figure 4.3.

3. What aspects of Asset Management help an organization succeed the most?

1. Recognize that the process is **long-term**. Incremental activity is going to be the norm. Key positions should be civilian to ensure continuity. From an enterprise level, funding MUST ensure that the end of a projected **lifecycle** is the replacement, not the extension of, that asset. If for example 75 years of roofing decisions (sustainment) does not end with a new roof but merely keeping it running another xx-years due to fiscal constraint, not sure we're going to get true value
2. **Commitment to facility investment priorities**, well-defined **service life expectations**, **adequate resources**.
3. **Leadership**. There must be **leadership commitment** to focusing on supporting the mission and objectives of the organization by realizing value from the organization's assets. This **leadership commitment** should result in a management-system approach to effective asset management linking assets and asset management to **Air Force strategy**. Can be reflected in **AM policy and strategy/objectives**.
4. Having **organizational leadership** publishing and communicating the **documented policies and process** that drive behavior.
5. **Leadership buy in**. If **senior leadership** is not on board to **support methodology** and associated results, the program will not work and the base as a whole will suffer.
6. Knowing where greatest risk of failure is in order to guide future **investment**.
7. Success in asset management is understanding what consists of an organization's inventory and how that inventory **provides value** to the organization. Once value is defined, communicated and understood, an organization can effectively make sound asset management decisions."
8. **Operationalization**. **How are the concepts employed at the day to day level**
9. The aspects of AM that help an organization is its a deliberate approach to maintaining an asset vice a crisis approach. It enables **predictive maintenance requirements** which improves **resource planning and allocation** and ultimately ensure s the **right investments** at the right time to minimize **life cycle costs**.

Figure 4.3: Round One, Question 3 Results

4.2.4 Round One, Question 4.

From the responses to 'What are the best people/organizations that you have seen do asset management well? What did they do well', the researcher identified the following themes: description of a non-specific trait, a specific Air Force entity, none/no idea, and private sector organizations. In the highlights, the description of a non-specific trait is identified in purple, a specific Air Force entity is identified in blue, none/no idea is identified in yellow, and private sector organizations are identified in green. The responses and themes are shown in Figure 4.4.

4. What are the best people/organizations that you have seen do Asset Management well? What did they do well?

1. No real opinion. think AFCEC and bases are still getting started
2. Proactive organizations with a focus on legitimate long-range planning efforts, appropriate prioritization of facilities and resources, commitment to long-range facility investment planning requirements (i.e., facility investment, avoidance of re-prioritization, limited "risk acceptance" in facility investment.
3. I have not personally witnessed AM done well...
4. Private sector companies that understand the true cost to maintain and operate their assets.
5. Minot AFB has a good asset mgt element in place but lacks the engineers to support designs and analysis.
6. I have not had experience with organizations outside the AF doing AM.
7. Amazon.com, Google, Apple, Hartsfield Atlanta International Airport, and the 52nd Civil Engineer Squadron. All of these organizations have a clear understanding of their inventory and how that inventory provides value to their organization. Furthermore, each organization has invested resources (manpower) in ensuring the link between assets and organizational mission is crystal clear.
8. AFCEC/CP, 52 CES ...make asset management concepts part of day to day business practices. Its inherent in what they do, not an additional consideration
9. I have read articles that have highlighted organizations that have used AM principles well. The common traits indicated a more centralized approach to activity management ie having complete inventory/condition data so that requirements could be planned for and completed at the right time to achieve lower life cycle costs. Additionally, the organizations leverage strategic sourcing of applicable assets so to enable lower procurement costs as well as training for maintenance personnel.

Figure 4.4: Round One, Question 4 Results

4.2.5 Round One, Question 5.

From the responses to ‘How are you judged on effective asset management, and how does your boss rate your performance on it?’, the researcher identified the following themes: a judgment that is distinct from other responses, and not being judged at all. In the highlights, a judgment that is distinct from other responses is identified in green, and not being judged at all is identified in yellow. The responses and themes are shown in Figure 4.5.

5. How are you judged on effective Asset Management, and how does your boss rate your performance on it?

1. Think this is going to be highly problematic as annual appraisal/award cycle favors high impact attention getting news. That is NOT the pace of asset mgt. I am not personally rated on this and do not manage assets at AFCEC/COO. However, we are trying to develop improved guidance to the bases on how to accomplish this. Publication of a revised Ops Engr Playbook is an example of what we would call a success. We also advised AFIT on the revamping of the 436 Ops Engr course.
2. Not at all. There is an education piece to Asset Management that requires emphasis at the Group, Wing, and MAJCOM levels. Mission availability of facilities and lack of failure are key indicators of successful performance.
3. I am not judged on asset management, but I do rate employees based on their ability to support and enable more effective asset management. Specifically, I rate them on elements and standards related to improving asset visibility and requirements identification so that we can develop creative courses of action around various ways and means to inform leadership decisions.
4. My office would be judged on our ability to issue policies & guidance and strategy that drives asset management behavior. rategy that leverages asset management principles.
5. Are we getting what we pay for in utility privatization? Are we supporting the shops in their planning? Are we spending money on the right assets?
6. My boss doesn't judge me on how well I do AM, nor did my boss's when I was a CES/CC.
7. I'm judged my the message I communicate to the field on asset management philosophy. My success is measured by how many students graduate my courses and how happy they are with the course they recieved.
8. How much \$\$ you get for projects (not necessarily the right answer, but a current reality
9. We are in the infancy phases of implementing AM for the AF. However, one of the key challenges my boss is asking me to come up with is strategies for implementing AM across the Transportation Network and Pavements portfolio in the AF. Strategies center around how do we want to "mature" the activities and what are the most important activities we have in terms of mission. This is not true asset management, but it applies risk mitigation to assets that we deem are less important to the accomplishment of the AF mission. So once strategies are developed, we will be judged on how we mature the activity and ensure it performs at the desired level.

Figure 4.5: Round One, Question 5 Results

4.2.6 Round One, Question 6.

From the responses to ‘What incentives do you have to do asset management well? How well do they work’, the researcher identified the following themes: personal motivation, more money for their own organization, and no/few incentives. In the highlights, personal motivation is identified in green, more money for their own organization is identified in blue, and no/few incentives is identified in yellow. The responses and themes are shown in Figure 4.6.

6. What incentives do you have to do Asset Management well? How well do they work?

1. **Personally none** - my role is to provide tools to allow others to do asset mgt well. **We're judging ourselves** on what we are doing but do not think senior leadership recognizes fully what is needed and making this a priority at their level to manage and influence progress.
2. **Good stewardship: Personal desire** to see money spent in the best way to benefit the mission and the taxpayer.
3. **I do not have any organizational incentives. My incentives drive from my own understanding of the value of asset management to the organization.** That incentive works well. So, one might deduce that the more people understand about the value of good asset management, the better more they may be self-incentivized to do it well.
4. **I have very few** - because i am not directly responsible for the actions to maintain our assets. .
5. **Job satisfaction.** AM is not an asset across the Air Force yet. It's still a program that is not fully supported.
6. I believe the incentives may be growing with the centralization of **FSRM funding.**
7. **Leadership buy in that what we're doing is the right decision for the broader cause, rather than only our own**
8. Currently, **incentives in AF asset management is all tied to the IPL.** You have to play by the business rules if you want centralized funds. Makes people conform to the business rules, but maybe not totally buy in to WHY we do that and why its important
9. **Incentives to do asset management well include well maintained assets performing at the desired level and what is costing.**

Figure 4.6: Round One, Question 6 Results

4.2.7 Round One, Question 7.

From the responses to ‘How do you know if you are doing asset management well?’, the researcher identified the following themes: unsure/don’t know how to tell, absence of premature facility failure, meeting performance standards, sub AMP progress, more funding for the base, greater PM (preventive maintenance)/CM (corrective maintenance) ratio, and a generic metric that is self-evaluated. In the highlights, unsure/don’t know how to tell is identified in purple, absence of premature facility failure is identified in blue, meeting performance standards is identified in green, sub AMP progress is identified in yellow, more funding for the base is identified in pink, greater PM/CM ratio is identified in orange, and a generic metrics that is self evaluated is identified in gray. The responses and themes are shown in Figure 4.7.

7. How do you know if you are doing Asset Management well?

1. At base level there should be **slow but steady progress within a Sub-AMP activity** showing that all the assets in a class are migrating to a common condition level and are achieving close to the projected usable life. At the enterprise level there would be **slow progress towards common performance standards** thru funding strategies designed to bring sub-performing assets up while accepting risk on those performing well
2. **Absence of premature facility failure.**
3. **We do not have measures of performance or effectiveness to assess how well we are doing AM.** Though, anecdotally, we do seem to be doing better as an enterprise in terms of typical "benefits" of asset management to include: informed asset investment decisions, and managing risk.
4. That is a great question - **I think many people would say that they don't have sufficient information to know how well they are doing.** If we lack information on the condition or performance of our assets - how can we say we know we are doing well? **In my office, we have not set strategy with performance standards** that informs others what targets they are to achieve with these assets.
5. Are we getting **additional funding** each year to support facility/infrastructure fixes? Are we using BUILDER results to get those **funds** that are required?
6. **Not sure.**
7. When students realize that what I'm teaching them is what they've been thinking all along. Asset management as a concept is far from new, and not unique to the CE enterprise, it's used across functions, we just call it something different. Look to A6, A3 and the rest of A4 communities for reference.
8. There are a number of key performance indicators, but I think the best are **rates of emergency work orders** and **PM/CM** ratios...tries to get at how proactive are we being about maintaining our assets vs. reactive when things break.
9. **Metrics will determine how well you are doing.** Understanding the requirements, COAs, and resources needed to maintain assets will show how well you are doing.

Figure 4.7: Round One, Question 7 Results

4.2.8 Round One, Question 8.

From the responses to 'What are the results of poor asset management, and how would you assess/measure these', the researcher identified the following themes: increased costs, poor/uninformed decision making, and premature failure. In the highlights, increased costs are identified in green, poor/uninformed decision making is identified in purple, and premature failure is identified in yellow. Highlighted in gray is the assertion that metrics for asset management do not exist by respondent #3, and the suggestion for a new metric by respondent #7. The responses and themes are shown in Figure 4.8.

8. What are the results of poor Asset Management, and how would you assess/measure these?

1. Failure to achieve projected life span of asset. Increasing costs due to deferment of SMS generated work items at time recommended in order to extend asset life in 'sweet spot'. Failure to drive incremental improvement across both a base and enterprise in overall condition and performance within asset classes, e.g. fixing fires vs measured approach following long-term strategy
2. Un-prioritized facility investments, excessive/un-necessary recapitalization costs, haphazard facility investment.
3. Poor AM results in inefficient and ineffective processes. Organizational activities may be stovepiped and not integrated while capabilities are suboptimally provided. We currently do not have metrics for AM, however, we do see the increased workload pressures on those responsible for good AM practices across the enterprise which indicate poor AM.
4. Failures of equipment, outages due to poorly timed or absent sustainment efforts. Unwise investments in a facility that does not meet the organizations goals or is too degraded to justify the expense.. Poor application of labor
5. Not sure.
6. Investing limited dollars in least critical requirements. Not sure how to measure.
7. 1. Resource decisions that are not in line with an organization's objectives. 2. Short sighted investments made as a result of not understanding the cost of those decisions. We could easily measure this by quantifying the cost of asset management decisions to higher value assets that did not receive investment as a result of that uninformed decision. We cannot quantify this without a true understanding of value.
8. Chasing your tail and never having enough time and money to do mission critical work
9. Additional costs will be the most tangible results for an enterprise with poor AM.

Figure 4.8: Round One, Question 8 Results

4.2.9 Round One, Question 9.

From the responses to 'How have you seen asset management principles successfully communicated to leadership (Group/CC and above)?', the researcher identified the following themes: poorly communicated or not communicated at all, general communication, using scoring models, risk, and helping leaders understand why. In the highlights, poorly communicated or not communicated at all is identified in yellow, general communication is identified in purple, using scoring models is identified in green, risk is identified in blue, and helping leaders understand why is identified in pink. The responses and themes are shown in Figure 4.9.

9. How have you seen Asset Management principles successfully communicated to leadership (Group/CC and above)?

1. Not as applicable to my position. However, I believe senior CE leadership adopted this philosophy but failed to organize to staff, resource, and measure progress by deferring 90% of decisions to base level. Lack of actions, for example not pursuing staffing of R&O at base level per guidance in PAD 12-03 is an example of giving highly mixed signals on how important asset mgt is
2. Logic-based facilities and resource prioritization (i.e., mission dependency index scoring), risk-based approach to resource allocation.
3. There have been attempts at communicating AM principles, but they generally fall short in truly articulating benefits of AM and how we measure. They typically end up being simply presentations of how we use scoring models to prioritize projects/investments and create base-level AMPs as extent of AM.
4. There is a AFIT class on Asset Management, but i think the target audience is CE officers. Our org used to produce a Wing Commander in-brief about CE generally - it did reference Asset Management briefly i think. In my base level role as Asset Management Flight Chief, we also cited it in the Facility Boards we held with Wing and Group Commanders to get approval on the facility investment list we submitted for MAJCOM review (at the time before R&M was centralized at AFCEC).
5. Briefings. CC symposiums.
6. I have not. It's usually more about chasing models to get more funding.
7. Informing leadership WHY the investment we recommend is the right decision to support the broader mission. Leaders will usually make the right decision given the right information, we (engineers) generally do not provide them with the right information.
8. AFCEC has done a decent job communicating the centralized IPL process at the GO level. AF leadership is on board with the concepts and process. Wg/CCs and below sometimes do not share that same enthusiasm and that is where we should focus communication efforts
9. Yes. MG Carter and MG Eulberg have done job communicating AM principles. Their message was we must apply AM to smartly manage the enterprise to meet mission requirements and address resourcing impacts.

Figure 4.9: Round One, Question 9 Results

4.2.10 Round One, Question 10.

From the responses to ‘How can you tell if asset management principles have been broadly adopted within the squadron?’, the researcher identified the following themes: understanding at all levels, periodic meetings/sustained message, proper prioritization, efforts towards a complete inventory, staff is adequately manned, emphasis on proactive decision making, root cause analysis is performed on reactive decisions, and alignment with mission. In the highlights, understanding at all levels is identified in red, periodic meetings/sustained message is identified in yellow, proper prioritization is identified in

pink, efforts towards a complete inventory is identified in orange, staff is adequately manned is identified in green, emphasis on proactive decision making is identified in blue, root cause analysis is performed on reactive decisions is identified in purple, and alignment with mission is identified in gray. The responses and themes are shown in Figure 4.10.

10. How can you tell if Asset Management principles have been broadly adopted within the squadron?

1. The unit's senior leadership would show sustained interest by holding periodic meetings to review status, discuss strategy, and provide supporting resources. Key positions would be filled. Priority would be placed on proactive actions versus reactive. Reactive decisions would require root-cause analysis to determine if applicable to other assets and measures taken and tracked to correct.
2. Consistent messaging, "buy-in" at the lowest working level, transparency in project prioritization (elimination of "favors" or "Chief's/SNCO/JNCO Mafia" special projects or reprioritization))
3. Similar to Justice Stewart's definition of hard core pornography: "I know it what I see it". Adoption of AM principles within a squadron should permeate the culture of the squadron. Not just lip-service that "we all do AM", but truly a part of their culture, processes and decision making.
4. I think it would be in the way that troops in CE Ops interacted on a work order, how they communicated beyond the shop level to the R&O element, and how feedback on an asset was discussed at the Work Order Review Board, and when the R&O element or CEO collaborates with CEP to determine when a repair or sustainment effort goes beyond in-house work. When the updates are made to our data systems that communicate facility project requirements based on feedback from staff who are maintaining them and understand their performance as well as the standards they should be meeting.
5. The number of people that have come from other Flights for answers/assistance. If folks are asking questions related to AM and the way ahead, they're getting the message and are willing to support it.
6. Not sure.
7. An appreciation for making smarter (not harder) decisions in elements of work prioritization, scheduling, project priority and management. A concerted effort to build an asset inventory database. Efforts undertaken at various levels (shop, element, flight, squadron) to codify or define the value that assets bring to the installation's mission.
8. When shop craftsmen are involved and understand the process
9. First, buy-in from their leadership who emphasize why we need to do and instill their people to do. Once the message is rec'd and acted upon, I can tell if it is broadly adopted by how well they are using the information collected to maintain their assets and ultimately knowing the the "heath" of the activities (based on performance stds).

Figure 4.10: Round One, Question 10 Results

4.2.11 Round One, Question 11.

From the responses to ‘How can an organization ensure that its asset management efforts are continuously improving?’, the researcher identified the following themes: reflection/review of data, senior leader/base involvement, commitment to continuity, transparent prioritization, commitment to quality data, and a culture of innovation. In the highlights, reflection/review of data is identified in orange, senior leader/base involvement is identified in yellow, commitment to continuity is identified in green, transparent prioritization is identified in purple, commitment to quality data is identified in gray, and a culture of innovation is identified in red. The responses and themes are shown in Figure 4.11.

11. How can an organization ensure that its Asset Management efforts are continually improving?

1. Senior leader involvement and commitment to long term plans created by predecessors and passed to successors
2. Constant communication vertically within the chain of command and horizontally across the installation, transparency in prioritization process, buy-in from stakeholders (commanders/mission owners)
3. An organization must employ some sort of management system with measures of effectiveness and performance. I am strong advocate for leveraging the international standard ISO55000/1/2. I recommend AF/CE utilize a management system approach to encompass Ends, Ways, and Means and to measure and improve effectiveness and efficiency.
4. The org needs to properly staff key roles where the lack of knowledge can break those connections at the squadron. If CE does not support the application of these efforts in the field, all the Strat Comms and policy in the world won't fix it. And the org must understand how it is doing across the enterprise, and make adjustments as needed.
5. Review the program. Review the results.
6. By ensuring quality/maintained data and putting investment towards greatest risk area.
7. By aligning its direction with the direction of the Air Force at large, and an insatiable appetite for understanding their inventory and how that inventory provides value.
8. Encourage a culture of innovation. Reward out of the box thinking and encourage bottom-up ideas
9. Performance monitoring and researching and acting on asset improvements.

Figure 4.11: Round One, Question 11 Results

4.2.12 Round One, Question 12.

From the responses to ‘How would you distinguish effective from ineffective asset management’, the researcher identified the following themes for effective asset management: appropriate investments, progress towards defined metrics, proactive actions, quality data, and an ingrained philosophy. In the highlights, appropriate investments are identified in green, progress towards defined metrics is identified in yellow, proactive actions are identified in blue, quality data is identified in purple, and an ingrained philosophy is identified in pink. From the responses to this question, the researcher identified the following themes for ineffective asset management: poor prioritization/decision making, poor progress towards defined metrics, incorrect allocation of resources, inefficient organization, reactive actions, lack of an ingrained philosophy, and a lack of quality data. In the highlights, poor prioritization/decision making is identified in red, poor progress towards defined metrics is identified in yellow, incorrect allocation of resources is identified in green, inefficient organization is identified in orange, reactive actions are identified in blue, lack of an ingrained philosophy is identified in pink, and a lack of quality data is identified in purple. The responses and themes are shown in Figure 4.12.

12. How would you distinguish effective from ineffective Asset Management?

1. Effective asset mgt would make progress toward board targets defined as the goals of each sub-AMP/AMP. Ineffective would make less optimal decisions driven by non-engineering factors like command interest and result in urgent needs later on in an asset's lifespan
2. Effective Asset Management would be characterized by appropriate, timely, informed facility investments. Ineffective Asset Management would either result in either just-in-time facility investments (well-informed investments with respect to need, scope, and budgeting, but reactive rather than pre-emptive in timing)
3. Effective AM helps the organization achieve it's desired effects in the most efficient manner. CE should employ the AM process within the Combat Support Construct to deliver desired effects. Ultimately, effective/ineffective AM is distinguished based on AM Policy/Objectives and associated measures of effectiveness.
4. Ineffective could be many things - one form of ineffective Asset Management might be the expenditure of lots of effort and resources that does not ultimately lead to better outcomes for the organization. That might be because we aren't using the data we collect, or we aren't investing smartly to maximize value, or we have gaps in training, skills, policies or bandwidth that prevent us from implementing these efforts effectively.
5. Is the squadron leaning toward being proactive vs reactive.
6. See answer the question 11. [By ensuring quality/maintained data and putting investment towards greatest risk area.]
7. Effective: We spent \$10 dollars on the greatest risk to the base's, MAJCOM's or Air Force's mission, Ineffective: We spent all \$10 this year, let's do it again!
8. How much money we are spending on target on time. Most previous metrics involve how much we spend. Effective asset management should be concerned with how we spent it.
9. I would say an effective AM organization has ingrained the principles into their daily activities from top to bottom, an ineffective AM org has not.

Figure 4.12: Round One, Question 12 Results

4.2.13 Round One, Question 13.

From the responses to ‘What metric(s) do you believe best indicate that an organization is effectively applying asset management principles?’, the researcher identified the following themes: system performance measures that are improving, following priority lists, complete/accurate condition inventory, fewer commander inquiries, absence of critical infrastructure failure, maintaining ‘Air Force Common Output Level Standards (AFCOLS), reduced lifecycle costs, and the percentage of personnel trained. In the highlights, system performance measures that are improving are identified in blue, following priority lists is identified in purple, complete/accurate condition inventory is identified in red, fewer commander inquiries is identified in pink, absence of critical infrastructure failure is identified

in yellow, maintaining AFCOLS is identified in green, reduced lifecycle costs is identified in orange, and the percentage of personnel trained is identified in gray. Additionally, the suggestion for another metric is highlighted in a bolder yellow than the absence of critical infrastructure failure. The responses and themes are shown in Figure 4.13.

13. What metric(s) do you believe best indicate that an organization is effectively applying Asset Management principles?

1. See other responses
2. Absence of system failure while maintaining a baseline quality of life/mission availability standard.
3. We need metrics for BOTH outcome effectiveness and process efficiency through performance management and continuous improvement.
4. I'd love to know that answer. I'm not sure if it is cost per unit area of various facility types. Or percent runtime between failures, or an average facility condition for a given portfolio. We have discussed that in some ways we are still trying to begin this effort - and that we lack an understanding of how our asset are performing - beyond those that can put eyes on the assets directly.
5. Are BUILDER/PAVER/ROOFER scores going up? Are we complying with priority lists? are we receiving fewer commander to commander inquiries?
6. 1). Completeness/accuracy/quality of the data, 2). Investment versus risk and condition
7. From what I have seen, there is a direct correlation between asset inventory completion and "success" as I have generally defined it. There is also a direct correlaton between success and leadership buy-in at the Element Superintendent level and BELOW (not above).
8. Maybe adopting a similar metric like AFPC uses to evaluate their management of human capital. They get judged on percentages of assignments that are consistent with an ADP. What if we judged spending on how consistent it is with established requirements and priorities, not just how much we executed.
9. Performance, life cycle costs, and % personnel trained (as to why and what they need to do).

Figure 4.13: Round One, Question 13 Results

4.2.14 Round One, Question 14.

From the responses to ‘How do you think the Air Force *should* measure success in Asset Mangement?’, the researcher identified the following themes: differences between planned/prioritized work and actual work performed, progress towards broad goals, capability/mission availability, understanding from subordinates, whether or not the ‘Integrated Priority List (IPL) is generated from BUILDER program inputs, 100%

complete facility inspections, the ability to inform decisions, and the amount of work generated by AMPs. In the highlights, differences between planned/prioritized work and actual work performed is identified in yellow, progress towards broad goals is identified in green, capability/mission availability is identified in blue, understanding from subordinates is identified in purple, whether or not the IPL is generated from BUILDER inputs is identified in red, 100% complete facility inspections is identified in pink, the ability to inform decisions is identified in orange, and the amount of work generated by AMPs is identified in gray. The responses and themes are shown in Figure 4.14.

14. How do you think the Air Force *should* measure success in Asset Management?

1. Commitment rates to plans, e.g. % of deviation from what and when planned vs actual. Progress toward broad goals across asset classes as mentioned earlier
2. 1) Investments: Judge facility investments and recapitalization against planned facility investments -- investment/recap exceeding planned investment rates indicated poor forecasting, rationary investment, or potentially addressing facility "wants" rather than facility "needs". 2) Quality of life/mission availability -- determine the quality of the facilities using an objective standard relating to mission availability, comfort, aesthetics, functionality, etc.
3. We need to stop thinking in terms of programs and start thinking in terms of capabilities and processes (ref Combat Support Construct). Using a consistent AM Process (e.g. ISO55000/1/2 AM System) better enables the synergistic employment of functionals to provide capabilities. Once we codify this within an AM Policy aligned to organizational goals, we can identify the appropriate metrics for measuring success.
4. I have similar thoughts to the previous answer i gave. We've heard a tale from an AFIT instructor about a MAJCOM or HAF general officer who would visit an office somewhere and ask an Airman "How are things going today?" The Airmen would invariably answer "Fine, sir". And the GO's follow up was: "How do you KNOW that?" And sometimes the Airmen could explain why. That to me would be a sign of success - when airmen at the squadron understand the role they play in keeping things running well and how they inform decisions and awareness at various elvels of the org. And that they think they THEY also benefit from this increased understanding.
5. Look at the IPL. Is it still based on 'nice to have' or bona fide needs based off the BUILDER. Is BUILDER up to date adn are assessments true? If CEOE was just stood up,there shouldn't be 100% assessments.
6. Good question. Once we can use it as a tool to inform programming/budgeting decisions.
7. It's hard to measure success, since success from one perspective is not successful from another. I don't believe it should measure success, it should reward it. Success should be *defined* as making the right investments. How many emergencies did a base have in a year? How much work was internally generated by AMPs and Sub-AMPs? How much risk was bought down by the IPL? How well did the efforts of engineers support the AFSMP (AF Strategic Master Plan) and the CFL Flight Plan? Reduce the delta between what you did and what you planned, that's success in it's broadest sense.
8. See above [Maybe adopting a similar metric like AFPC uses to evaluate their management of human capital. They get judged on percentages of assignments that are consistent with an ADP. What if we judged spending on how consistent it is with established requirements and priorities, not just how much we executed.]
9. See 13. [Performance, life cycle costs, and % personnel trained (as to why and what they need to do).]

Figure 4.14: Round One, Question 14 Results

4.2.15 Round One, Question 15.

From the responses to 'What elements of asset management are most important to the Air Force CE enterprise?', the researcher identified the following themes: the understanding of costs, information about assets, the ability to support the mission,

a decision making paradigm, and the understanding of risk. In the highlights, the understanding of costs is identified in purple, information about assets is identified in yellow, the ability to support the mission is identified in pink, a decision making paradigm is identified in red, and the understanding of risk is identified in green. The responses and themes are shown in Figure 4.15.

15. What elements of Asset Management are most important to the Air Force Civil Engineer enterprise?

1. Ability to view asset inventory and condition via SMS. Creation of guidelines for base level risk management guiding programming
2. Timely investments, stewardship of taxpayer dollars, mission availability, functionality of facilities.
3. All six elements of AM are important (Strategic Planning; Organization and People; Decision Making; Life Cycle Mngt; Knowledge Mngt; Risk and Review). But, when accomplishing Strategic Planning, we would assess our current and desired level of AM ability/maturity. This element is crucial to set the enterprise, establish performance objectives/metrics, and improve integration.
4. It would be to be able to demonstrate that we are effectively and efficiently managing our built and natural infrastructure in a way that supports the mission and makes the best use of our resources (both financial and human capital).
5. Data analysis of maintenance and repair and cost of facility
6. Completing the data gathering and building an effective IT tool to manage it.
7. INVENTORY. The more we understand our inventory, the more we understand how it provides the organization very tangible value. VALUE. We need to understand how our assets provide value to the multi-layered organization.
8. 1.) IPL process 2.) Using AMP data to build the POM
9. Enterprise long-term & short-term goals/expectations, Asset visibility, requirements ID, planning/programming (includes COA development), resourcing, performance management

Figure 4.15: Round One, Question 15 Results

4.2.16 Round One, Question 16.

From the responses to ‘What elements of the Air Force’s asset management policies *should* bases commit to regardless of cost or effort required?’, the researcher identified the following themes: complete asset inventory, lifecycle planning, manpower, enabling the mission, space management, requirement focus, 100% PM completion, and the notion that nothing is that important. In the highlights, complete asset inventory is identified in

yellow, lifecycle planning is identified in green, manpower is identified in red, enabling the mission is identified in blue, space management is identified in purple, requirement focus is identified in pink, 100% PM completion is identified in orange, and the notion that nothing is that important is identified in gray. The responses and themes are shown in Figure 4.16.

16. What elements of the Air Force's Asset Management policies *should* bases commit to regardless of cost or effort required?

1. Inventory and assessment are foundational - without them nothing else can move forward
2. Facility investments to maximize service life of buildings and systems.
3. While Life Cycle Management would drive to smart long-term financial decisions, bases must commit to elements of AF AM policies that pertain to enabling mission effectiveness with cost considerations...depending of course on alignment of said mission with National Security Strategy.
4. Becoming more active in Space Management, and breaking down residual hangups about unit integrity, etc. Also for CEO and CEP to be open-minded about focussing on the REQUIREMENT versus the Project. People need space within which to work. They may not need to continue occupying a PARTICULAR space. And to take seriously the idea about where a facility is in its lifecycle and proactively make adjustments to their IT systems to reflect the knowledge they gain from their hard work.
5. manpower.
6. Considering regardless of cost or effort required, none.
7. 1. A fully stood up R&O section that generates requirements and optimizes the squadron's investments. 2. 100% of scheduled PM is executed. 3. asset inventory completion in accordance with OSD memo.
8. FCAs....everything built on data, if that is not supported, the rest is worthless
9. Accurate inventory and condition assessments with data input into SMS system or other Business information system.

Figure 4.16: Round One, Question 16 Results

4.2.17 Round One, Question 17.

From the responses to ‘What behaviors/mindsets are most critical to success in asset management?’, the researcher identified the following themes: shared understanding & education, buy-in, critical/innovative thinking, lifecycle focus, making decisions based on the data, being proactive, and a risk management focus. In the highlights, shared understanding & education is identified in green, buy-in is identified in blue, critical/innovative thinking is identified in purple, lifecycle focus is identified in yellow,

making decisions based on the data is identified in pink, being proactive is identified in red, and a risk management focus is identified in orange. Additionally, the concept that asset management should be a leadership philosophy is identified with a bolder yellow highlight. The responses and themes are shown in Figure 4.17.

17. What behaviors/mindsets are most critical to success in Asset Management?

1. Commitment to a very long term approach that transcends typical military tours
2. Education of programmers, resource managers, and chain of command on desired end state for Asset Management; stakeholder (customer) buy-in .
3. Integration; Collaboration; Pursuit of "And"; Negotiation ; Stewardship
4. Understanding the concepts of Asset Visibility, Requirements Identification, and that each of us plays a role in ensuring the wise investment of public funds to perform our mission.
5. Critical thinking. The AF cannot continue to do business the way we always have. Look to maintain those facilitates that need it.
6. Data-informed resourcing decisions.
7. Innovative, unconstrained and critical. We have to innovate if we want to do this with such a large, disjointed and diverse organization. Asset management is beyond a management philosophy, it's a leadership philosophy.
8. Being proactive, innovative thinking and looking at things through the risk management lens
9. Buy-in and understanding of all personnel critical to the process.

Figure 4.17: Round One, Question 17 Results

4.2.18 Round One, Question 18.

From the responses to ‘What Air Force-unique limitations most hinder asset management success?’, the researcher identified the following themes: a lack of manning/resources, short term thinking, working past the good idea of the day, lack of importance to wing leaders, the notion that good asset management isn’t exciting, inefficiency that results from intentional redundancy, risk aversion, and the size of the enterprise. In the highlights, a lack of manning/resources is identified in red, short term thinking is identified in yellow, working past the good idea of the day is identified in purple, lack of importance to wing leaders, the notion that good asset management isn’t exciting is identified in blue, inefficiency that results from intentional redundancy is identified in

pink, risk aversion is identified in orange, and the size of the enterprise is identified in yellow-green. The responses and themes are shown in Figure 4.18.

18. What Air Force-unique limitations most hinder Asset Management success?

1. A lot! Limited commitment to a very long term approach. Belief this is a wing CC job-asset mgt really belongs to the enterprise. Wing DO does not decide what plane to fly and how long to keep, done by a AF weapons system mgt office. Need same outlook for facilities/infrastructure. Hard to link decision made by predecessor to incumbent's role for appraisal and awards-culture is big and splashy with immediate results as proof of excellence. The IDEAL unit award winner, say best Ops Flight, would have had no emergencies short of acts of God. Asset mgt actions, starting with routine boring PM, coupled with just-in-time corrective actions would produce life spans and performance matching desired curve over life of asset. Ultimately the failure will likely be in no funding
2. Command rotations, constantly changing work forces (i.e., military PCSes), continuous transformation initiatives driving new beddown requirements and facility re-purposing
3. Concepts such as Adaptive Basing . 1-year O&M money that is year-to-year inconsistent regarding distribution, timing, and amount. Built-in inefficiencies that account for direct mission-effects that are required to support O-Plans but unnecessary during steady-state.
4. Our relatively slow rollout of Tririga has not helped our enterprise benefit from this new tool. I think there is some fatigue out there about this capability we've been hearing about for years but still hasn't gotten to many bases. Also, we have done a poor job of ensuring squadrons are consistently staffed, trained, or have the tools to do this work effectively.
5. "That's the way we've always done it"
6. Human resourcing.
7. Risk aversion. We aren't a for profit company, so the financial benefits realized by implementing AM are not drivers like they are in a competitive marketplace. Innovation is often stagnated due to our fears of leadership ostracizing us if our ideas do not ultimately pan out.
8. Funding restrictions....the bureaucracy of our finance system makes artificial boundaries and limitations on how we can use resources. We are also a non-profit national defense organization that kills people and blows things up for a living. Some things we do will be inherently against asset management principles....its hard to determine when we should make the smart business decision and when we need to spend/invest just because its best for the mission.
9. Not sure we have unique challenges hindering AM, other than our bottom line is not profits. In my opinion buy-in from at all levels and subsequent resourcing hinders AM. The pure size of our enterprise contributes to the problem.

Figure 4.18: Round One, Question 18 Results

4.2.19 Round One, Question 19.

From the responses to ‘What Air Force-unique advantages most promote asset management success?’, the researcher identified the following themes: centralization of

resources & leadership, awareness from new organization, civilian work force, resource shortage that drives efficiency, the availability of large government resources for properly identified risks, the diversity of the workforce, and the potentially broad application of asset management. In the highlights, centralization of resources & leadership is identified in yellow, awareness from new organization is identified in green. civilian work force is identified in blue, resource shortage that drives efficiency is identified in purple, the availability of large government resources for properly identified risks is identified in pink, the diversity of the workforce is identified in red, and the potentially broad application of asset management is identified in orange. The responses and themes are shown in Figure 4.19.

19. What Air Force-unique advantages most promote Asset Management success?

1. IMSC and AFCEC centralization has potential to make a difference
2. Centralized resources (this comes at the expense of commander discretion, though)
3. Centralized management and leadership of I&MS activities and funding under AFIMSC.
4. The stand-up of AFIMSC should help drive some of this behavior. A recognition by CE leadership at A4C and AFCEC that we must continue to pursue these goals . And a growing awareness of these tools at the local level.
5. I think the AF has the most civilianized CE work force of all the Services. That brings with it folks who are a little more open minded to change. We just need to let them change things.
6. Not sure.
7. The bona fide need for asset management principles to stretch every taxpayer's dollar to the greatest extent. The cross functional implications if we can figure this whole thing out. the other organizations and functions within the air force that are faced with the same problems we are. We need to get together as an Air Force to figure this problem out, not just Civil Engineers.
8. Other side of that sword is that there are tons of resources available if we can accurately identify and defend the need. Uncle Sam has deep pockets that some commercial organizations do not. If we use asset management to show our true requirements, and big AF leadership agrees, we can have the resources we need without the restrictions of stockholders/boards etc..
9. Centralized training programs for personnel entering the AF. AF's diverse workforce contributes to resolving and tackling challenges like implementing AM, therefore I see this a unique advantage.

Figure 4.19: Round One, Question 19 Results

4.3 Round Two Results

The round two results section provides all of the responses to round two of the Delphi Technique questionnaire. The first three questions are open ended clarifications on input from the first round of the questionnaire. The responses were quite lengthy, and are shown verbatim in the appropriate subsections. In questions 4 through 12, respondent were asked to rank themes that were identified in round one, in order of importance. Respondents were then asked to indicate how certain they were in their rankings on a scale of 1-5, where 1 indicated extremely uncertain, 2 indicated uncertain, 3 indicated undecided, 4 indicated certain, and 5 indicated extremely certain. As indicated in the methodology, the researcher used conditional formatting within excel to then color the responses on a spectrum from green to red, where green indicated the most important ranking, and red indicated the least important ranking. Some respondents chose to provide additional commentary on either their rankings or their certainty. When additional commentary was provided, an asterisk was added to either the ranking or the certainty. An explanation of the additional comment is provided below the corresponding figure. Finally, question 13 allowed respondents to provide additional feedback at the end of the survey, if they felt that was necessary.

4.3.1 Round Two, Question 1.

Question 1 of round two is as follows:

Based on the responses in the previous questionnaire, most individuals have either not seen asset management done well, or have only seen it done well in private industry. Why do you think Air Force organizations are not doing asset management well? Are their significant or widespread “barriers to entry?

The responses to this question are enumerated below:

1. “AF culture does not promote or nurture long-term program management regarding infrastructure lifecycle oversight. No single tour (for mil-

itary) can be credited with anything concrete, decisions on maint and re-pair have long emergence times in the impact to an assets lifespans. The barrier to entry is our mindset is to react to emergencies (rewarded) versus methodical slow-moving actions that are not very visible (or dramatic). Tough sell for leadership.”

2. “Organizational process changes are challenging under even the most ideal conditions. Air Force-unique barriers to entry include workforce education, regular changes in leadership at all levels of the chain of command, and motivation. The AFIT training program on asset management is a phenomenal resource, but the career fields exposure is potentially limited by seats available, workforce availability for TDYs from home station, and/or leadership commitment to asset management implementation. Changes in leadership at all levels of the chain of command can result in shifting mission and installation priorities contrary to established facility investment strategies education at all levels of the chain of command is critical to consistent implementation of asset management principles across the Air Force.”
3. “The reason is twofold: 1) it is a drastic organizational change requiring buy-in from every level (not just leadership, and not just engineers) and 2) we have a budget that must be spent entirely every year. Until this changes, we will continue to measure success by how much we spent, not how we spent our money.”
4. “Historically, the AF Civil Engineer (those primarily charged in the AF to do AM), has been and currently “is structured around functional services/stovepipes. The structure includes organizational structure (Engineering, Operations, Housing, etc), Policies, Processes, Budgeting,

Funding, Rewards and People Good AM requires cross-functional and integrated activities. Achieving a structure to enable good AM can be accomplished in large part by efforts of the AF/CE community. For example, as we re-write AFIs, we could do so to be consistent with how our asset management approach takes our functionally-aligned stovepipes, and forces them to work together (i.e. Integration) within an asset management process to execute the AF CE Core Tasks. (This is also consistent with the Combat Support Construct.) So, my recommendation is that we reaccomplish our AFIs following our Core Tasks:

- Planning and Programming AFI
- Acquire and Divest AFI
- Operate and Sustain AFI
- Protect and Recover AFI

Obviously we can look at many other areas within AF/CE control that better enables the integration needed for good AM. One approach may be to support CE Squadrons in establishing an asset management System (similar to as described in ISO 55000/1/2) with guidance on how to measure and improve their local level of maturity in application of that management system. In other words, the desired “end” is good asset management. We can use various ways and means to get there. The means include money and manpower and are unlikely to change anytime soon. But we can re-look at our “ways”. PAD12-03 established a decent asset management system. Unfortunately, I doubt many people read or applied it “cover-to-cover”. Instead we each read our functionally-respective chapter without consideration for how we each fit into the bigger system.” Moreover, AF/CE needs to consider “outside” the

installation support asset management objectives which is essentially life-cycle activities, and include the “mission or bigger-AF organizational objectives. This is about pursuit of the “AND. Installation AND Mission. Efficiency AND Effectiveness. Local Installation AND Enterprise. Etc We accomplish this by recognizing and aligning the shared goals of “installation management and mission partners. Much of this could be accomplished through relevant and robust use of AFCOLS with mission-adjudication-governance (also recommended through ISO 55000/1/2).”

5. “Those bases that are doing, or trying to do, asset management are typically undermanned. Weve all been trying to get 100% inventories, 100% building assessments, and in some cases struggling to work with Tririga. The result is that we cant get in front of the requirements. We are still trying to make it work and we havent had the opportunity to show what the advantage would be to asset management done well. That leads to the “weve always done it that way syndrome.”
6. “Yes. “Barriers to entry are 1) The bureaucracy, red tape and financial rules and regulations inherent to government. For example, we identify requirements in “buckets based on fiscal thresholds (minor construction ; 1M) when those limits that drive our business rules are arbitrary in terms of asset management principles. 2) We have an ingrained culture pre-disposed to tradition and status quo that has not had to worry about AM principles in the past. All of the personnel in leadership positions right now grew up in a culture of spending money to a bogey.here is my piece of the pie, now Im gonna figure out what I want to spend that on vs. what are my actual requirements and how much do I truly need to meet a minimum level of service. 3) Training and education in AM is lacking.

The AF rolled out some bumper sticker slogans and nebulous principles dispersed throughout a number of PAD, P-Plan annexs and playbooks, then dumped some new IT systems in the mix without any up front education and training. We are trying to catch up to the demand now, but the implementation of AM was heavy on the program and process at the headquarters level without any real strategy for bringing the practitioners in the field along at the same pace. 4) There is no real AM strategy, not any 1 organization owns it as a program. Different organizations are working on AM “stuff or tools that support it, but there is not a well-defined finish line or end state for what AM in the AF should look like and how everyones efforts are integrating to get us there.”

7. “Why not doing well- you need to understand how we were/were not doing. My opinion is the AF was more prone to “react to Mx items vice predict mx requirements. We had RWP but because of other priorities and resource constraints the work was just not getting done when it needed to be done. Hence an important part of Life-cycle mx was not being done at the right time leading to sub-par AM. Additionally, we were chasing the \$ for things we thought we needed to get done (some truly needed, and some not) without understanding or “listening to what we needed to do wrt built infrastructure. This “deafness led to some improper repairs where we replaced an asset instead of addressing the root cause of the problem and repairing it. Why my thoughts: we lacked an accurate asset inventory, condition ratings(aka asset visibility) and a predictive maintenance capabilities (training too) to derive requirements that were based on standard criteria. Additionally, we did not have the right corporate mind-set of where we needed to spend our next

dollar. The mindset shared was what can I get for my base or command. Essentially, leaders were graded on the \$ they recd and spent vice what they saved doing the right repairs at the right time. Once we get full asset visibility, predictive modeling capabilities, and an informed enterprise, we can overcome the barriers to entry; however, it will take time. Big organizations such as the AF have a harder time to adjust (change), especially since the BL is not for profit.”

4.3.2 Round Two, Question 2.

Question 2 of round two is as follows:

“Based on the responses in the previous questionnaire, many individuals stated that they were not judged or rated on their asset management performance. Additionally, many individuals stated that they were either not incentivized or were only motivated by their personal reasons. How should the Air Force incentivize individuals to strive for excellence in their asset management performance?”

The responses to this question are enumerated below:

1. “Tough nut to crack. An entirely new set of data feeding AM focused KPIs is needed. AM practitioners would, long with their leadership, have these to help show status along portfolio performance measures.”
2. A directive approach to compliance through the Unit Effectiveness Inspections (UEI) will likely motivate installation adaptation of asset management. Incorporation of asset management under the broader inspectable area of “resource management would highlight commanders stewardship of financial and physical resources. Although commanders should still be allowed discretion for managing risk and mission

accomplishment at their installations, an understanding that they are directly accountable through the UEI program for diverting from asset management investment strategies would likely increase motivation.”

3. “The Air Force would have to define asset management performance first, which is not that simple. Currently, the AF isnt in the business of “incentivizing but rather “enforcing, maybe there should be an AFI that mandates the use of AM principles, or one that defines them altogether.”
4. “Accountability to an individuals contribution to the Asset Management System/Process should be through the personnel management and appraisal program. For Civilians, the new DPMAP allows for that, provided elements and standards are appropriately assigned. This same approach could be used with military as well. In order to create appropriate and relevant SMART elements and standards, they need to be aligned to the organization mission and goals. This requires effort in planning and likely could be accomplished by standardizing elements and standards that could be leveraged from all base civil engineer organizations.”
5. “Its in the PAD that thats what were supposed to be working toward from the CEOE element. Those people in those positions, whether civilian or military, need to have their job descriptions written around those requirements. Otherwise, those people become the go-to folks for everything other than Asset Management because its not a requirement”
6. “This goes back to number 1 above. The AF process is driven by budget and execution rates. BCEs are graded on meeting 80/20 mandates, how much work is being executed and how happy they keep their leadership. I havent figured out the magic answer yet, but figuring out a performance

metric that grades what you spent money on and how efficient you were with funds available vs. how much you spent is a start.”

7. “My opinion incentivizing may work if properly rolled out, but will require “change management efforts to codify it. How to do it, Im still in pondering it, but offer my thots. Using monetary incentives in the AF may actually “rob from what needs to be done from an AM perspective. For example, one base because the they have not done the things required (IE BUILDER inputs) to get their asset condition visible and requirements known at a higher level may truly have “better candidates for investment, but get penalized, which actually increase the \$ needed to repair in the future. If I had all the cards, I would roll-out a mandate to get Asset visibility done first. Have a period of QC/QA of the data, allow corrections, and then start deriving the enterprise requirements from the predictive modeling IT systems (SMS). Since AF is not a “for profit organizationwe would need to accept that we may deviate from AM principles to reward the ones that do it on-time and do it well. The incentives added would be adding \$ to address what the models tell us they need (sustainment \$/Major M&R). In cases where models show a deduction in sustainment \$, I would look at adding their “next project in the IPL that is below the IPL funding line (to a certain \$ amount). Please note there is a push to do FCAs via contract. So, the incentive concept would need to change to “How well does the base sustain data collected.this would be graded on a 5 yr schedule!”

4.3.3 Round Two, Question 3.

Question 3 of round two is as follows:

“How should the Air Force incentivize organizations to implement asset management principles?”

The responses to this question are enumerated below:

1. “Develop Asset Management award(s) for best base program. New R&O award (for Ops flight)? See examples at The Institute of Asset Mgt: <https://theiam.org/about/Support-Recognition/IAM-Awards>”
2. “Hold commanders at all levels accountable for the way money is spent. In my time commanding CE squadrons at two MAJCOM bases, the logic of investing in the long-term viability of infrastructure systems sold well at facilities board meetings, but Wing Commanders were interested in leaving a visible legacy (club renovations, DV lounge upgrades, fitness center modifications, etc.) as well as appealing to higher headquarters senior leaders wants and needs. Rather than orient our facility investment model solely towards worst first, allow a Wing/CC withhold as a percentage of PRV for discretionary spending on quality of life (this need not be an outrageous sum of moneythe \$100k CINC IEA award was the gold ring every Wg/CC chasedthat would be a legitimate starting point). Make the use of that discretionary sum part of the Unit Effectiveness Inspection for the Wing/CC as well.”
3. “Rewarding units that plan ahead. Rewarding innovative approaches to communicate risk and provide alternatives that provide value while maximizing return on investment.”
4. “I believe we should acknowledge the importance of the AF/CE “Way of accomplishing our “Ends by recognized the level of maturity to which we strive via our AF/CE Strategy. We can then measure our progress toward this level of maturity through “Ability to statements.”

5. “Just before standing up AFIMSC, the AF stated that there was going to be a pot of money for small SRM projects < \$1M. Those were projects that didnt compete at the IPL because theyre too small. If that pot of money came to fruition, it would fund all those projects that BUILDER says are due. BUILDER shows the estimated cost to bring the amber and red ratings to green. It shows the infrastructure projects that are not visually appealing or on someones want list but follow that asset management principle of “where is the best place to spend AF money. Support the principles with money and this program will take off.”
6. “Fund to identified requirements on a bases AMP. This is a multi-year process, because our AMPs inform the POM 4 years out, but if the long term requirements generated by AMPs today actually translate into real money showing up at the base in 4 years, that will institutionalize the way we look at AMP management. ” Creating performance based metrics (i.e ASCE infrastructure report card type format) to judge performance of a base and having the quantification that goes into those grades be based on AM principles that should be rewarded would start to get people thinking about how well the base performs and supports the mission rather than how much money did we execute.
7. “See above.”

4.3.4 Round Two, Question 4.

Question 4 of round two is as follows:

“The following are the top themes for successful asset management. Please rank them in order of importance from 1 = most important to 5 = least important.”

The responses to this question are shown below in Figure 4.20:

Item	#1	#2	#3	#4	#5	#6	#7
Adequate resources	3	4	5	5	3	2	4
Adhering to established policy/strategy	4	5	4	2*	2	5	5
Focusing on the long-term lifecycle of assets	1	1	1	3**	4	3	2
Leadership buy-in	2	2	3	1	1	1	1
Making the Right Investments	5	3	2	4	5	4	3
Certainty	4	5	4	4	4	4	4

*(note: provided established policy/strategy directs successful asset management)

***(note: this is good...and we also need to focus on mission requirements at same time)

Figure 4.20: Round Two, Question 4 Results

4.3.5 Round Two, Question 5.

Question 5 of round two is as follows:

“The following were the top themes identified as “ways to know if you are doing asset management well. Please rank them in order of how effective you think they are indicating asset management performance, where 1 = most effective and 5 = least effective.”

The responses to this question are shown below in Figure 4.21:

Item	#1	#2	#3	#4	#5	#6	#7
Absence of premature facility failure	3	2	4	3	3	1	2
Greater PM/CM Ratio	5	5	3	4	1	3	3
Meeting defined performance standards	1	3	1	1	2	2	1
More Funding for the Base	4	4	5	5*	4	5	5
Sub Amp Progress	2	1	2	2	5	4	4
Certainty	4	4	4	4	4	3	3

*(NO!! We shouldn't measure MORE funding...we should measure THE RIGHT funding)

Figure 4.21: Round Two, Question 5 Results

4.3.6 Round Two, Question 6.

Question 6 of round two is as follows:

“Based on the responses in the previous questionnaire, most individuals stated that asset management principles have not been successfully communicated to leadership (Group/CC and above). Others indicated that asset management has been successfully communicated using the following methods. Regardless of your response in the previous questionnaire, please rank these communication methods in order of how effective you think they would be in helping your leadership understand the importance of asset management, where 1 = most effective and 3 = effective.”

The responses to this question are shown below in Figure 4.22:

Item	#1	#2	#3	#4	#5	#6	#7
Explanation of Risk	2	2	2	1	2	2	2
Understanding “why” we should perform Asset Management	1	1	1	2	3	1	1
Using mathematical scoring models to show effectiveness	3	3	3	3	1	3	3
Certainty	4	5	4	4	4	3	4

Figure 4.22: Round Two, Question 6 Results

4.3.7 Round Two, Question 7.

Question 7 of round two is as follows:

“The following were listed as ways to identify whether or not asset management principles have been broadly adopted within the squadron. Please rank them in order of importance to asset management adoption, where 1 = most important and 8 = least important.”

The responses to this question are shown below in Figure 4.23:

Item	#1	#2	#3	#4	#5	#6	#7
Adequate manning in key Asset Management positions	1	4	8	8	1	1	5
Assets are continually prioritized by mission	8	5	7	5	5	5	8*
Effort towards complete/accurate inventory	2	6	3	3	3	4	2
Emphasis on proactive decision making	3	3	2	2	4	6	4
Periodic meetings on Asset Management/ Sustained message	4	8	6	7	7	8	6
Proper Prioritization	7	1	4	4	6	3	3
Root Cause analysis is performed on reactive decisions	5	2	5	6	8	7	7
Understanding at all levels	6	7	1	1	2	2	1
Certainty	3	4	4	4	2	3	4

*This should naturally occur!

Figure 4.23: Round Two, Question 7 Results

4.3.8 Round Two, Question 8.

Question 8 of round two is as follows:

“The following were listed as the top ways an organization can ensure that its asset management efforts are continuously improving. Please rank them in order of importance, where 1 = most important and 6 = least important.”

The responses to this question are shown below in Figure 4.24:

Item	#1	#2	#3	#4	#5	#6	#7
Commitment to continuity	2	3	3	5	3	2	4*
Commitment to quality data	3	2	1	4	2	1	2
Culture of innovation	6	6	2	2	1	5	3
Reflection on/review of data	1	5	5	3	4	6	6
Senior Leader/Base involvement	4	1	4	1	5	3	1
Transparent prioritization	5	4	6	6	6	4	5
Certainty	4	5	3	4	3	4	4

*Better word...to asset management

Figure 4.24: Round Two, Question 8 Results

4.3.9 Round Two, Question 9.

Question 9 of round two is as follows:

“The following were listed as the best indicators that an organization is effectively applying asset management principles. Please rank them in order of how effective the indicator is that an organization is effectively applying asset management principles, where 1 = most effective and 8 = least effective.”

The responses to this question are shown below in Figure 4.25:

Item	#1	#2	#3	#4	#5	#6	#7
Absence of critical infrastructure failure	3	2	4	6	1	6	4
Complete/accurate condition inventory	4	4	3	4	3	3	2
Fewer commander inquiries	8	8	5	7	4	5	6
Following priority lists	5	5	6	5	5	4	5
Improvement on existing measures of performance	1	3	1	3	2	1	3
Maintaining/meeting minimum Air Force Common Level Output Standards (AFCOLS)	6	7	8	1	7	7	7
Percent/Number of trained personnel	7	6	7	8	8	8	8
Reduced lifecycle costs	2	1	2	2	6	2	1
Certainty	3	4	3	4	4	3	4

Figure 4.25: Round Two, Question 9 Results

4.3.10 Round Two, Question 10.

Question 10 of round two is as follows:

“The following were listed as ways that the Air Force should measure success in asset management. Please rank them in order of how effective they are at measuring successful asset management, where 1 = most effective and 8 = least effective.”

The responses to this question are shown below in Figure 4.26:

Item	#1	#2	#3	#4	#5	#6	#7
Amount of work generated by Activity Management Plans (AMPs)	3	5	1	5	2	2	8
Difference between prioritized work lists and work actually performed	7	1	3	6	3	3	7
Mission Availability	6	2	8	4	8	8	2
Number/Percent of Airmen who understand Asset Management	8	8	5	3	7	6	4
Percent of inventory inspections complete	4	6	6	7	5	5	5
Progress towards broad enterprise goals (AMPs, Strategic plans, etc.)	2	4	4	1	6	1	1
Whether or not the data is used to inform decisions	1	3	2	2	4	4	3
Whether or not the Integrated Priority List (IPL) reflects Builder outputs	5	7	7	8	1	7	6
Certainty	4*	5	3	4	4	5	3

*1-4 pretty certain. The remaining choices were not especially good measures in my opinion so ranked as best I could

Figure 4.26: Round Two, Question 10 Results

4.3.11 Round Two, Question 11.

Question 11 of round two is as follows:

“The following were listed as elements of Air Force asset management philosophy that bases should commit to regardless of cost or effort required. Please rank them in order of importance, where 1 = most important and 7 = least important.”

The responses to this question are shown below in Figure 4.27:

Item	#1	#2	#3	#4	#5	#6	#7
100% PM completion	2	6	5	6	4	4	7
Adequate manpower	7	7	7	7	2	6	6
Complete/accurate asset inventory	1	3	3	4	3	2	2
Enabling the base's mission	5	1	1	1	6	1	1
Focus on requirements over wishes	4	2	2	2	1	3	5
Life cycle planning	3	4	4	3	5	5	3
Space Management	6	5	6	5	7	7	4
Certainty	3*	4	4	4	4	4	4

*Difficult to rank when items did not appear to be comparable

Figure 4.27: Round Two, Question 11 Results

4.3.12 Round Two, Question 12.

Question 12 of round two is as follows:

“The following were listed as the most critical behaviors/mindsets to success in asset management. Please rank them in order of importance, where 1 = most important and 8 = least important.”

The responses to this question are shown below in Figure 4.28:

Item	#1	#2	#3	#4	#5	#6	#7
Being proactive over reactive	5	1	8	8	2	6	4
Buy-In	2	5	7	1	1	3	1
Education	7	7	1	6	7	4	6
Innovative/Critical thinking	6	8	3	5	3	5	7
Life cycle focus	1	2	6	3	5	7	3
Making decisions based on the data	3	3	5	4	4	2	5
Risk management focus	4	4	4	2	6	1	2
Shared Understanding	8	6	2	7	8	8	8
Certainty	4	4	2	4	3	4	4

Figure 4.28: Round Two, Question 12 Results

4.3.13 Round Two, Question 13.

Question 3 of round two is as follows:

“Please use the space below for any additional commentary on the questions or concerns related to asset management.”

Respondents 1, 2, 3, 5, 6, and 7, did not have any commentary or questions to add. Respondent 4 had the following response:

“I encourage you to read ISO 55000/1/2 and The International Infrastructure Management Manual to get a deeper/more comprehensive understanding of Asset Management and the Asset Management System.”

4.4 Round Three

The round three results section provides all of the responses to round three of the Delphi questionnaire. The round three questionnaire asked participants to rate their level of agreement with rankings that were aggregated from round two rankings. Participants were also given space to provide commentary on their level of agreement. If a participant indicated disagreement with the ranking, they were asked to use the commentary space to provide an explanation. When available, commentary will be provided below the data tables containing the responses to each question. For all questions in round three, an agreement of 1 represents “strongly disagree, 2 represents “disagree, 3 represents “neither agree nor disagree, 4 represents “agree, and 5 represents “strongly agree.

4.4.1 Round Three, Question 1.

Participants were asked to rate their level of agreement on the following ranking of the top themes for successful asset management.

1. Leadership buy-in
2. Focusing on the long-term lifecycle of assets

3. Adequate resources
4. Making the right investments
5. Adhering to established policy/strategy

Table 4.1: Round Three, Question 1 Agreement

Respondent	Agreement
1	4
2	5
3	5
4	1*
5	4
6	5
7	2**

*Various ways and means can be used to achieve your ends. Considering resources as “means, and there will always be competition for those limited means, I believe that having consistency in and discipline in adhering to our “ways is ever more important. Our “ways should be established in policy/strategy based on leadership direction. Because of this, I would move #5 to #2. Leadership buy-in is first and leadership in-turn establishes the Asset Management policy/strategy. Everything else hinges on this. The policy/strategy establishes the strategic context for Asset Management and reinforces leadership buy-in. It should be established based on understanding the external environment, internal environment, and customer perspective. If

there is no good Asset Management policy/strategy, or if there is no adherence to it, then leadership loses faith in the execution of asset management, and it all falls apart very quickly.

**I wouldve moved “adhering to policy behind “leadership because that would cause all others to fall in line.

4.4.2 Round Three, Question 2.

Participants were asked to rate their level of agreement on the following ranking of the top themes for ways to know if you are doing asset management well.

1. Meeting defined performance standards
2. Absence of premature facility failure
3. Sub-AMP progress
4. Greater PM/CM Ratio
5. More funding for the base

Table 4.2: Round Three, Question two Agreement

Respondent	Agreement
1	5
2	4
3	4*
4	4**
5	5
6	5
7	4

*PM/CM ratios will not be as valuable for building and building systems as they are in industrial manufacturing where the metric is more widely used.

**I would swap #2 and #3 only because I believe the process is so important to the performance. Sub AMP Progress reflects the process and following a process. I assume we already have, and have had for decades, very little premature facility failure. This may not necessarily be attributed to doing AM well, rather, it could be due to reacting at the right time to avoid failure, or throwing excess funds at facilities close to failure (each are not good AM practices.).

4.4.3 Round Three, Question 3.

Participants were asked to rate their level of agreement on the following ranking of the most effective ways to communicate asset management principles to leadership.

1. Understanding “why we should perform asset management

2. Explanation of risk
3. Using mathematical scoring models to show effectiveness

Table 4.3: Round Three, Question 3 Agreement

Respondent	Agreement
1	5
2	5
3	5*
4	4
5	5
6	5
7	4

*Emerging Installation Health Assessment tool will greatly aid this

4.4.4 Round Three, Question 4.

Participants were asked to rate their level of agreement on the following ranking of the ways to identify whether or not asset management principles have been broadly adopted within the squadron.

1. Understanding at all levels
2. Effort towards complete/accurate inventory
3. Emphasis on proactive decision making
4. Proper prioritization

5. Adequate manning in key asset management positions
6. Root cause analysis is performed on reactive decisions
7. Assets are continually prioritized by mission
8. Periodic meetings on asset management/Sustained message

Table 4.4: Round Three, Question 4 Agreement

Respondent	Agreement
1	5
2	5
3	5
4	4
5	5
6	4*
7	4

*I would add understanding and comprehension... folks may understand but comprehending and doing is the next level.

4.4.5 Round Three, Question 5.

Participants were asked to rate their level of agreement on the following ranking of the top ways an organization can ensure that its asset managements are continuously improving.

1. Commitment to quality data

2. Senior leader/base involvement
3. Commitment to continuity
4. Culture of innovation
5. Reflection on/review of data
6. Transparent prioritization

Table 4.5: Round Three, Question 5 Agreement

Respondent	Agreement
1	1*
2	4
3	4**
4	1***
5	5
6	5
7	4

*Priorities 4 and 6 should be swapped. Transparent prioritization reinforces the higher priority items. A culture of innovation, while important in improving organizations, can lead to a culture of “reinventing the wheel and continuous change...this can be counterproductive when consistency/predictability/repeatability underpin desired outcomes.

**Saw no particular value to the role of culture of innovation

***Like most things, if you want to ensure continuous improvement, you MUST have senior leader involvement. Senior Leader involvement must be #1 in all AM efforts. They need to understand, champion, cheerlead, direct, cajole, etc. Next, the AM journey should always evolve. Not major changes, rather continuous improvements and evolutions as AM abilities mature. We can only do this successfully if we have a culture of innovation where everybody, at all levels of AM have unity of effort and working toward the same effect.

4.4.6 Round Three, Question 6.

Participants were asked to rate their level of agreement on the following ranking of the best indicators that an organization is effectively applying asset management principles.

1. Improvement on existing measures of performance
2. Reduced lifecycle costs
3. Complete/accurate condition inventory
4. Absence of critical infrastructure failure
5. Following priority lists
6. Fewer commander inquiries
7. Maintaining/meeting minimum Air Force Common Level Output Standards (AF-COLS)
8. Percent/number of trained personnel

Table 4.6: Round Three, Question 6 Agreement

Respondent	Agreement
1	5
2	5
3	5
4	1*
5	5
6	4
7	5

*I consider Item 7 to be much higher (I recommend #1). Heres why. If AFCOLS are done right and are truly relevant to AF Organizational Strategy, then they would essentially become the “shared goals of Efficient AND Effective (in other words, meeting I&MS efficiency goals while enabling mission execution effectiveness). These shared goals would be established at the strategic level and in essence become part of the AM strategy/policy, and subsequently RESOURCED accordingly. So, if you have strategy (AFCOLS levels), and you resource your strategy, its important that you actually execute to that resourcing level and that is why meeting minimum AFCOLS is so important.

4.4.7 Round Three, Question 7.

Participants were asked to rate their level of agreement on the following ranking of the ways that the Air Force should measure success in asset management.

1. Whether or not the data is used to inform decisions

2. Progress towards broad enterprise goals (AMPs, Strategic plans, etc.)
3. Amount of work generated by Activity Management Plans (AMPs)
4. Difference between prioritized work lists and work actually performed
5. Percent of inventory inspection complete
6. Mission availability
7. Number/percent of Airmen who understand asset management
8. Whether or not the Integrated Priority List (IPL) reflects BUILDER outputs

Table 4.7: Round Three, Question 7 Agreement

Respondent	Agreement
1	1*
2	5
3	2**
4	3
5	5
6	4
7	2***

*Mission availability (ranked #6 above) should be the primary discriminator. If it isn't, it begs the question "why should the Air Force adopt asset management at all? Mission requirements/availability should be the primary reason we invest in infrastructure.

**Not sure how #1 can be achieved without #8 being higher, like around 3-5. % understanding asset mgt is ok but Id rank at base of list. If we all ‘understand but do not act upon or choose to ignore condition assessment and make life cycle investments when needed, and this mean senior AF, DoD, and Fed Govt decisions makers, then all the trained CE personnel will not make any difference.

***7 and 8 should be closer or at the top. As I understand AM, the main goal is to spend money and resources better. If properly employed then the BUILDER data would drive the IPL, not base wants. If nobody understands that then AM will not work.

4.4.8 Round Three, Question 8.

Participants were asked to rate their level of agreement on the following ranking of the elements of Air Force asset management philosophy that bases should commit to regardless of cost or effort required.

1. Enabling the base’s mission
2. Complete/accurate asset inventory
3. Focus on requirements over wishes
4. Lifecycle planning
5. 100% PM completion
6. Space management
7. Adequate manpower

Table 4.8: Round Three, Question 8 Agreement

Respondent	Agreement
1	5
2	5
3	3
4	4
5	5
6	5
7	4

No comments were provided.

4.4.9 Round Three, Question 9.

Participants were asked to rate their level of agreement on the following ranking of the most critical behaviors/mindsets to success in asset management.

1. Buy-in
2. Risk-management focus
3. Making decisions based on the data
4. Lifecycle focus
5. Being proactive over reactive
6. Innovative/critical thinking
7. Education

8. Shared understanding

Table 4.9: Round Three, Question 9 Agreement

Respondent	Agreement
1	5
2	4
3	5
4	4
5	5
6	5
7	4

No comments were provided.

4.5 Summary

This chapter provided the results from three rounds of Delphi technique questionnaires that were sent out to SMEs. Numerical answers were consolidated, and written responses or comments were provided verbatim in the appropriate sections. These results will be further explored and analyzed in the following chapter.

V. Conclusions

5.1 Introduction

This chapter concludes the research effort, and provides a summary of the study, a discussion of the findings, implications for practice, limitations, and future research opportunities.

5.2 Summary of the Study

This research study was conducted via the Delphi technique in order to generate consensus and develop policy. Open ended survey questions related to the research questions were emailed to subject matter experts in Air Force asset management. Survey responses from the 1st round of the Delphi technique questionnaire were then analyzed for themes. Respondents to the first round of the Delphi technique questionnaire were then asked to rank the identified themes in order of importance, as the 2nd round of the Delphi technique questionnaire. Ranking responses from the 2nd round of the Delphi technique questionnaire were summed to develop a suggested ranking, where the lowest total sums would be most important, and the highest total sums would be least important within a question. The suggested rankings were then sent to the questionnaire respondents as the 3rd round of the Delphi technique questionnaire in order to gauge agreement. Finally the levels of agreement on suggested rankings were analyzed and used to develop research conclusions and recommendations to the Air Force.

5.3 Discussion of the Findings

The research methods and survey questions were developed to answer the following four research questions:

1. How should success in asset management be objectively quantified?

2. What are the key components of success in asset management?
3. How can successful asset management principles benefit the CE community?
4. How can success in asset management be communicated and encouraged within the CE community?

The following subsections analyze the results of the three rounds of the Delphi technique questionnaires in order to develop understanding and potential answers to the research questions.

5.3.1 Round One.

Overall, the first round of the Delphi technique questionnaire proved to be very enlightening. Among the nine Subject Matter Experts (SMEs) that responded to the questionnaire, there are a wide variety of opinions and understanding of asset management. While different respondents were able to identify several aspects of asset management, no single respondent was able to provide a comprehensive explanation that included the expertise and recommendations of the other respondents. The researcher anticipates that if SMEs do not possess a comprehensive and shared understanding of asset management within the context of the Air Force, it is extremely unlikely that subordinates and less experienced practitioners of asset management in the Air Force would have a comprehensive or shared understanding either. This pervasive and wide ranging difference of opinions lead the researcher to believe that the Air Force would greatly benefit from a 'Strategic Asset Management Plan (SAMP), as recommended by the IAM and ISO(s) 55000-55002 [12, 21, 22].

5.3.1.1 Question 1.

When asked what asset management meant to the respondent, every participant had a slightly different answer, but all of them included some aspect of cost or value. This emphasis on cost makes sense, because asset management has been implemented

in government organizations primarily as a cost saving practice [6, 14, 16, 17]. Most respondents highlighted that asset management is an active process, but only two respondents mentioned the data that is used to inform that process. The research has shown that data and the quality of that data is incredibly important to being able to implement successful asset management in an organization [12, 17, 25–27, 30, 37, 40, 56, 59, 60].

5.3.1.2 Question 2.

When asked about the key elements of asset management, seven consistent themes arose among the answers: importance of inventory, intentional process, organizational alignment, resource focus, decision making paradigms, condition ratings and risk. Some respondents were able to identify six of those themes, but the average was only about four themes per respondent. This average could be improved, and consistency among respondents would likely be achieved if the Air Force were to publish clear and concise organizational asset management objectives.

5.3.1.3 Question 3.

When asked about what aspects of asset management help organizations succeed, four themes arose: leadership, proper investments, adherence to policy, and a long term lifecycle perspective. An analysis of the responses suggested three loose groups of opinions. These groups had three participants each and were broken into: focus on leadership and policy; investments and resourcing; and lifecycle focus. Only one of the participants focused on operationalization, which might indicate that employing the strategic concepts at a tactical level are less important to organizational success than the other themes. A consistent understanding of what helps foster success in asset management can be derived from case study analysis and research efforts such as this. Through prioritization and communication of key elements of asset management success, the Air Force could help foster success at all levels.

5.3.1.4 Question 4.

When asked about what people/organizations do asset management well, three different groups arose: those had not seen asset management done well, those that were aware of private corporations that practice asset management well, and those that were aware of specific Air Force organizations that do asset management well. Only three respondents were unable to identify any people or organizations that do asset management well. This presents a challenge, because it is easier to achieve success across an organization when there is an example of how achieve success. Of the nine respondents, only three were aware of private sector companies that have achieved asset management success, and only one participant was able to name specific companies. The last group of participants were able to identify specific Air Force entities that were doing asset management well. These last two groups presented a similar challenge as the first group, because if the SMEs were unaware of what successful asset management looked like, they will have to spend time and energy creating their own definitions in isolation. Based on these responses, the Air Force would likely benefit from identifying and sharing examples of successful organizations, so that subordinate units understand what to strive for.

5.3.1.5 Question 5.

The responses for how participants are judged or rated on asset management performance highlighted a significant problem for the Air Force. SMEs were either not rated on asset management performance at all, or were rated in ways that were unique and different for every individual. If the Air Force wants to promote asset management principles and mindsets, then the Air Force would benefit from the development of standard metrics for asset management performance. Research has shown that people are more likely do what they are rated or graded on, and that it is folly to expect one thing while incentivizing another [80].

5.3.1.6 Question 6.

The responses for what incentives are available for doing asset management well, highlight the same issues as in Question 5. Most respondents were either not incentivized at all or had internal incentives based on their own values. Relying on intrinsic belief systems or work ethic may convince some people to buy-in to asset management, but it is unlikely to convert the masses. The remaining participants identified organization incentives related to funding for projects. If the Air Force were able to develop and provide incentives for asset management performance, there would be more buy-in.

5.3.1.7 Question 7.

Much like Questions 5 and 6, the responses on how to know if you are doing asset management well highlights an issue with current Air Force asset management. Four of the nine SMEs indicated that they did not know how to tell if they are doing asset management well. The remaining participants identified methods, but none of the ideas were shared by more than two people. If SMEs don't know how or don't agree on how to gauge asset management performance, it is extremely unlikely that the majority of Air Force civil engineers understands how to gauge asset management performance either. This uncertainty and disagreement highlights the need for consistent and widely understood measures for asset management success.

5.3.1.8 Question 8.

When asked about the results of poor asset management, all but one of the SMEs highlighted increased or unnecessary costs. One of the largest challenges is that most organizations don't have a way to grasp how much money is being wasted through poor or improper investments in infrastructure. One potential way to address this challenge is through the use of predictive analytics and local area cost estimating. Once civil engineers are better able to predict when infrastructure will fail or degrade in service as well as

estimating the costs of different repairs, they will be better equipped to justify the correct investments that will save money over an asset's lifecycle.

5.3.1.9 Question 9.

When asked how respondents have seen asset management principles successfully communicated to leadership, about half of the respondents indicated that they had seen those principles communicated poorly or not at all. The literature on asset management emphasizes the importance of senior-leader buy-in [12, 19], so it is important the Air Force asset management practitioners understand the best ways to communicate asset management principles.

5.3.1.10 Question 10.

When asked how to tell if asset management principles have been broadly adopted within the squadron, the respondents had many divergent ideas. The most popular methods were a demonstrated understanding at all levels and periodic meetings with a sustained message from the unit leadership. Both of these methods underscore the importance of unit level leadership buy-in and the demonstrated understanding of asset management principles. Additionally, the diversity of responses reaffirms the notion that the Air Force would benefit from clear and consistent guidance about what asset management is, what it should be, and what it looks like.

5.3.1.11 Question 11.

When asked how an organization can ensure that its asset management efforts are continually improving, there were again nearly as many ideas as there were respondents. The top method (review of and reflection on collected data) underscores the importance of quality information to asset management success. Although only one individual mentioned the ISO 55000 series, it is very likely that the Air Force could benefit from utilizing published industry standards.

5.3.1.12 Question 12.

When asked how to distinguish effective from ineffective asset management, the responses centered around making the appropriate investments and making progress towards metrics. As stated previously in Question 8's analysis, the ability to make the right investment decisions would be bolstered by quality data and predictive analytics. Progress towards metrics is important, because it is difficult to improve what is not measured. Additionally, from the researcher's experiences, Air Force leaders are very focused on meeting and improving metrics. This focus on metrics in turn underscores the importance of measuring and thus incentivizing the right things.

5.3.1.13 Question 13.

When asked what metric(s) best indicate effective implementation of asset management principles within an organization, more than half of the respondents identified improving performance measurements. When taken in context with the responses to the other questions, the responses to this question further underscore the importance of establishing the correct metrics that encourage asset management success.

5.3.1.14 Question 14.

When asked how the SMEs believe the Air Force should measure success in asset management, more than half of the respondents emphasized the importance of making the right investments. Many of these SMEs indicate that investments can be judged based on how well actual projects match up with what would be recommended by sub-AMPs or condition-focused databases. One complication with this notion comes from the researchers' experiences that some individuals try to reshape condition assessments based on stated leadership priorities, rather than relying on accurate and high-quality data to generate project priorities. Although this may satisfy certain leaders, changing condition assessments in this way undermines the efficacy of asset management. As such, any system

or metric that compares actual work with recommended work will have to take this into account.

5.3.1.15 Question 15.

When asked what elements of asset management are most important to the Air Force Civil Engineer (CE) enterprise, all but one of the SMEs listed an understanding of costs. The emphasis on making better investments is consistent and echoed in the responses to other questions. Also of note, two thirds of the respondents saw that knowing more about the conditions of their assets and their inventory provided value to the enterprise.

5.3.1.16 Question 16.

When asked what elements of the Air Force's asset management policies that installations should commit to regardless of cost or effort, the respondents provided fairly diverse answers. The most popular element identified was a completed asset inventory because as some of the SMEs noted, a complete and accurate database is the foundation of asset management itself. Without complete or accurate information, it is difficult to make reliable decisions and/or make the optimal investments in facilities. Furthermore, complete and accurate information can only be achieved through consistent review and reassessment of the data.

5.3.1.17 Question 17.

When asked about the behaviors/mindsets that are most critical to success in asset management, participants provided many different responses. These disagreements in importance and priority, once again highlight the need for clear and consistent explanations and objectives to align asset management understanding and focus at all levels.

5.3.1.18 Question 18.

When asked about the Air Force unique limitations that hinder asset management success, the SMEs generated the following concerns that leaders at all levels should be aware of: resource constraints, short-term thinking, working past transformation fatigue,

lack of importance, the fact that good asset management isn't exciting, inefficiency from intentional redundancies, risk aversion, and the size of the Air Force enterprise. While all valid concerns, resource constraints and risk aversion are experienced to varying degrees in the private sector. Thus, it is not accurate to consider them to be unique to the Air Force.

Working past transformation fatigue is the notion that many individuals within the Civil Engineer community might see asset management as a fad or gimmick that isn't worth investing time and effort into. This situation is the result of numerous reorganizations and short-lived cost saving efforts within the past decade. In order to overcome this bias, asset management leaders at all levels must convey a consistent and persistent message about the importance of asset management principles to the unit and the Air Force at large.

While short term thinking is a prevalent issue for asset management in any organization it is compounded by the transient nature of military personnel. In private industry it is highly unlikely that almost all leaders within an organizational structure are swapped out every few years. In the military, however, this is fairly standard practice. In order to combat short term mindsets, it is important for senior CE leaders to convey a clear and consistent message about the importance of asset management.

Lack of importance is the notion that requirements to replace or repair infrastructure components are not followed as rigidly as requirements to replace or repair aircraft components. This is a valid concern, and is likely the result of the fact that aircraft failure is usually more catastrophic and expensive than infrastructure component failure. However, despite this difference, civil engineers might still find success by communicating through the similarities in requirements. Additionally, asset management could achieve greater legitimacy within the Air Force if base leadership, rather than just civil engineers, were also evaluated on the effectiveness of asset management at the base.

Effective asset management and infrastructure maintenance is not very exciting. The problem is that a CE unit will receive far more recognition for promptly resolving

facility emergencies rather than preventing facility emergencies in the first place. External recognition, in the form of awards and performance reports, are a large motivator within the Air Force. Consistently high annual evaluation ratings and recognition are all but required for advancement and promotion. To address this, senior CE leaders must understand and communicate the metrics that indicate effective asset management and encourage the appropriate type of asset management performance.

Intentional redundancies are necessary for high importance, no-fail missions within the Air Force. Surplus assets can reduce efficiency and unnecessarily strain resources. Because these redundancies are critical to the mission of the Air Force, civil engineers must understand and incorporate these challenges into planning and operations. Additionally, by having a better understanding of an asset's lifecycle costs through predictive analytics, civil engineers will be better primed to inform decision makers about the risk and cost trade-offs in having redundancies.

The final Air Force-unique challenge is the size of the enterprise. According to a 2015 baseline report published by the Department of Defense, the Air Force owns 127,880 assets, which includes buildings and structures. Like the Air Force, retail giant Walmart owns and operates buildings at various locations around the world. Even though Walmart is the largest private employer in the United States [81], it only operates 11,700 stores around the world [82]. The difference in scale between the Air Force and a very large private company (like Walmart), make it difficult to find relevant models of successful asset management for comparison. Thus, the size and diversity of the Air Force's mission may make it difficult to institute a single comprehensive asset management plan that may be sufficient for smaller organizations. The size of the Air Force enterprise is a very real concern and there might be value in future research that investigates a more decentralized asset management approach, as demonstrated by the Federal Highway Administration [64].

5.3.1.19 Question 19.

When asked what about Air Force-unique advantages that promote asset management success, the SMEs generated the following list: centralization of resources and leadership; awareness from new organization; civilian work force; resource constraints; deep government pockets; diversity of work force; and the potentially broad application of asset management. In order to achieve the greatest success, it is important for the Air Force to understand and leverage the unique advantages and capabilities possessed by the organization.

The first and most often highlighted unique advantage to the Air Force is the centralization of resources and leadership. The Air Force Civil Engineer Center (AFCEC) is responsible for enterprise leadership for Civil Engineers [83]. In order to best leverage this advantage, AFCEC must ensure that its asset management message is both clear and consistent. Additionally, as the leading organization, AFCEC must be responsible for communicating the importance of asset management to other non-CE organizations within the Air Force that might create conflicting obligations for base Civil Engineers.

Another suggested advantage of the Air Force is ‘the awareness from the stand-up Air Force Installation and Mission Support Center (IMSC)’. IMSC is a new organization, only announced back in 2014 [84], and is the organization that provides oversight to the finance, contracting, security forces and services field operating agencies [85]. Several survey respondents indicated that centralization under this new organization might help drive asset management principles across the organization. The researchers, based on their own experience are less optimistic about the advantages of IMSC. First and foremost, IMSC was developed to reduce staff costs [84], not to drive asset management principles to the Air Force. Secondly, any potential strengths of this new organization will have to overcome transformation fatigue, one of the Air Force-unique disadvantages previously identified. Thirdly, IMSC is focused on more than just the CE enterprise, which might limit its focus

on asset management. Despite these limitations, if properly communicated and prioritized, IMSC does have the potential to positively transform asset management in the Air Force.

The large civilian work force within the Air Force CE community was listed as another Air Force unique advantage. A stable civilian work force helps to overcome the transient nature of Active Duty military leadership. One SME indicated that the civilian work force is more open-minded to change. This is true in many instances, but cannot be accepted as a universal truth. Experience has shown that some civilian workers are actually less open-minded to change than their military counterparts due to transformational fatigue. In these instances, some civilian workers are less inclined to change because they perceive that they can outlast the current leader's emphasis on asset management. Some Active Duty military members on the other hand, may be more receptive to a leader's new priorities precisely because they themselves are new to a unit. The point is that not all of the civilian work force is open to change nor are all military members opposed to change. The true strength of the civilian work force is the continuity and corporate knowledge that they can provide at a location. Thus, it may be more important to get asset management buy-in from the civilian work force because it could pay dividends over a longer period of time.

Resource constraints, previously listed as an Air Force disadvantage, may also be an advantage. With a continued Air Force focus on reducing costs, asset management may be able to gain more traction if properly communicated through lifecycle savings. The foundation of this ability to leverage resource constraints for asset management however, is predicated on the proper understanding of costs and predictive analytics.

Another advantage, which seems to stand in contrast to resource constraints, is the ability of the Federal Government to provide additional funds for properly communicated risks. Private sector companies must rely on their owned capital, profitability, and loans from banks to generate resources. The federal government however, does not generate profit, and actually operates within debt. Thus if risks are properly understood and

communicated, the Air Force might be able to request additional funds based on risk to the mission.

Another Air Force advantage is the diversity of the work force. The Air Force CE community employs people in a wider variety of specializations and talents. This diversity in skill can also lead to a diversity of thought that can help develop new ideas, insights, and innovations. In order to best leverage this advantage, senior leaders must ensure that their decision-making efforts are informed by many individuals that possess a diversity of experience.

The final Air Force-unique advantage is the potentially broad application of asset management principles. The asset management industry itself is very diverse for this reason. If AFCEC is able to achieve consistent success applying asset management principles to the CE community, it is very possible that IMSC may find applications for asset management elsewhere within its organization. However for asset management principles to be openly received, it is important that AFCEC demonstrates its effectiveness first.

5.3.2 Round Two.

Round two of the Delphi technique study asked participants to provide three open ended responses that clarified round one answers and rank the themes identified in round one in order of importance. A commentary and analysis of the open ended responses was provided for questions 1 through 3. In order to analyze the rankings for questions 4 through 12, graphical representations of the data were created. Each included graph tracks a single theme in a solid colored line throughout all of the responses. Correlation plots were also developed as an analytical tool and are shown in Appendix C.

5.3.2.1 Question 1.

When asked why respondents believed Air Force organizations were not doing asset management well, and if there were any widespread barriers to entry, the SME's

emphasized the following challenges: cyclic leadership changes, difficult budgetary environment and rules, a pervasive bias towards fixing emergencies and avoiding preventive maintenance that wasn't as visible, under-use of asset management education, a lack of motivation/buy-in, organizational stovepipes, lack of manning and resources that prevent organizations from getting ahead, a lack of overall strategy or end state, and sluggishness from the size of the Air Force.

5.3.2.2 Question 2.

When asked how the Air Force should incentivize individuals to strive for asset management excellence, the SME's suggested that asset management could be directly apart of appraisals, unit funding, using organizational documents (such as AFI's and PADs) to explain why asset management is important. For commanders, the SME's also suggested that asset management performance could be tracked during unit effectiveness inspections (UEIs).

5.3.2.3 Question 3.

When asked how the Air Force should incentivize organizations to implement asset management principles, the SME's recommended the development of new asset management awards/recognition, holding upper level commanders responsible for how money is spent at all levels, providing discretionary funding, rewarding improvements in asset management maturity, creating a central fund that provides money for BUILDER requirements that are too small for the IPL, and earmarking future funding for requirements identified in AMPs.

5.3.2.4 Question 4.

In round two question 4, the top ranked theme for successful asset management was leadership buy-in, underscoring it's importance. Figure 5.1 shows a graphical representation of the responses to round two, question 4. In round one, the top suggested theme for successful asset management was leadership buy-in.

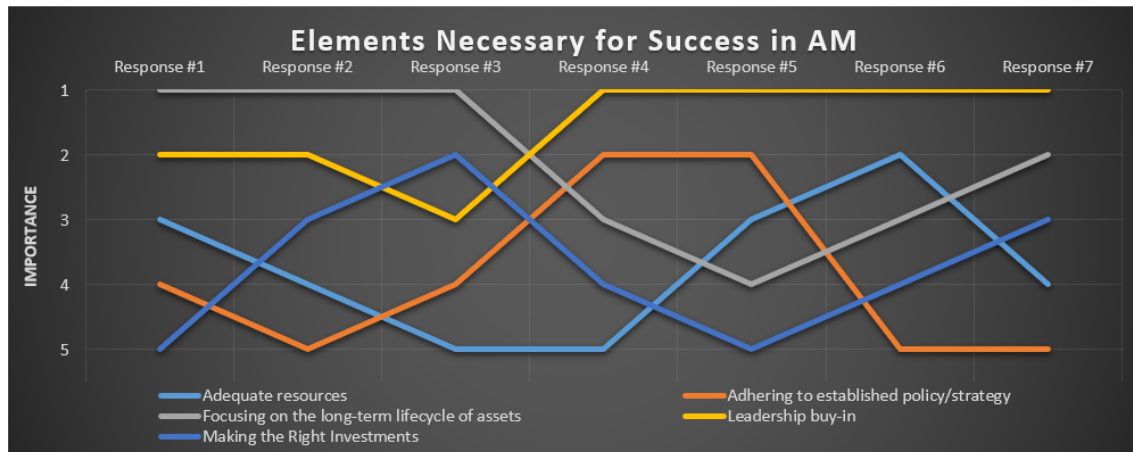


Figure 5.1: Round Two, Question 4 Graph

5.3.2.5 Question 5.

In round two question 5, the top ranked theme for successful asset management was meeting defined performance standards. Figure 5.2 shows a graphical representation of the responses to round two, question 5. In round one, the top suggested theme for ways to know asset management is being done well was an absence of premature facility failure. Furthermore, most respondents in round one indicated that they did not know how to tell if they were doing asset management well.

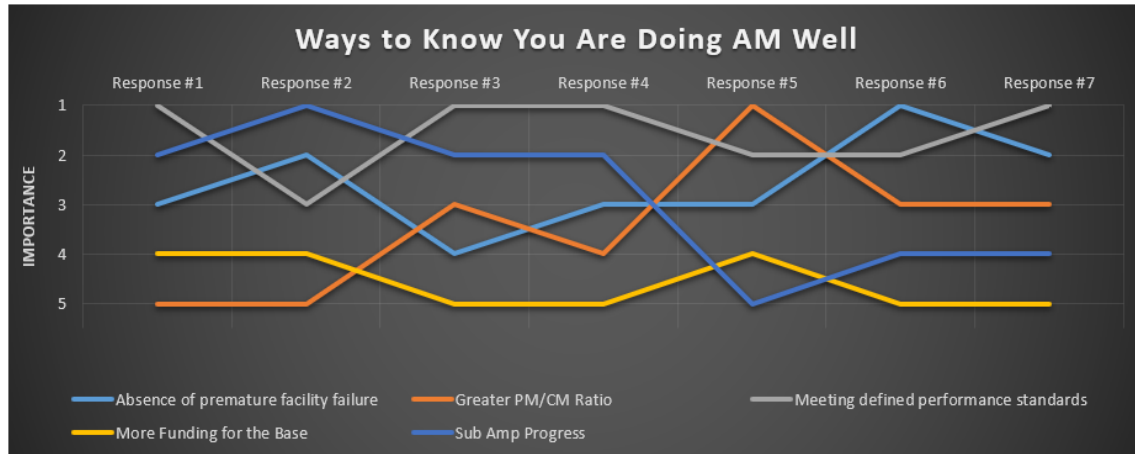


Figure 5.2: Round Two, Question 5 Graph

5.3.2.6 Question 6.

In round two question 6, the top ranked theme for communicating asset management principles was helping leaders understand the *WHY*. For question 6, five of the seven SMEs provided identical ratings, while the other two SMEs gave the only other two possible combinations. Figure 5.3 shows a graphical representation of the responses to round two, question 6. In round one, the top specific theme for ways to effectively communicate asset management principles to senior leadership was using available scoring models, although more respondents indicated that they had not seen asset management principles communicated well.

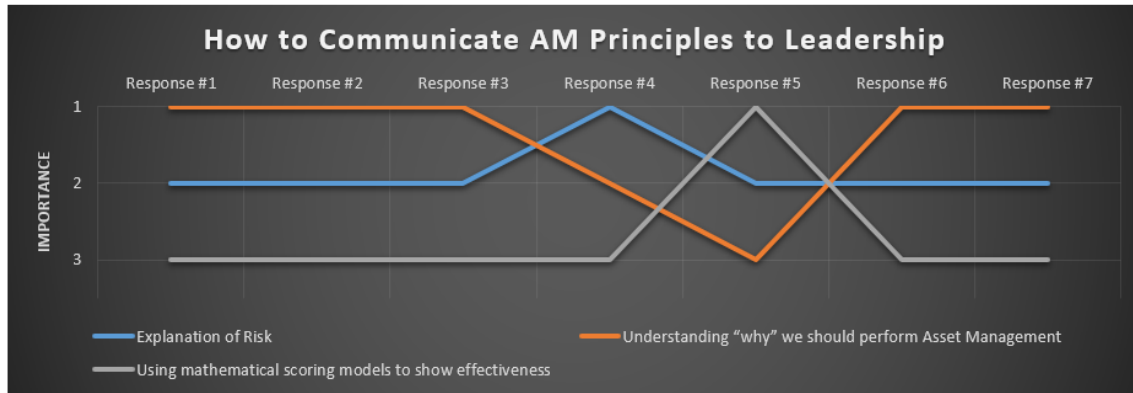


Figure 5.3: Round Two, Question 6 Graph

5.3.2.7 Question 7.

In round two question 7, the top ranked theme for ways to identify whether or not asset management principles have been broadly adopted within the squadron was also understanding at all levels. Figure 5.4 shows a graphical representation of the responses to round two, question 7. In round one, the top specific theme for ways to identify whether or not asset management principles were broadly adopted within the squadron was understanding at all levels of the organization. This consistent emphasis underscores the importance of clear and consistent communication at all levels, which helps develop understanding at all levels.

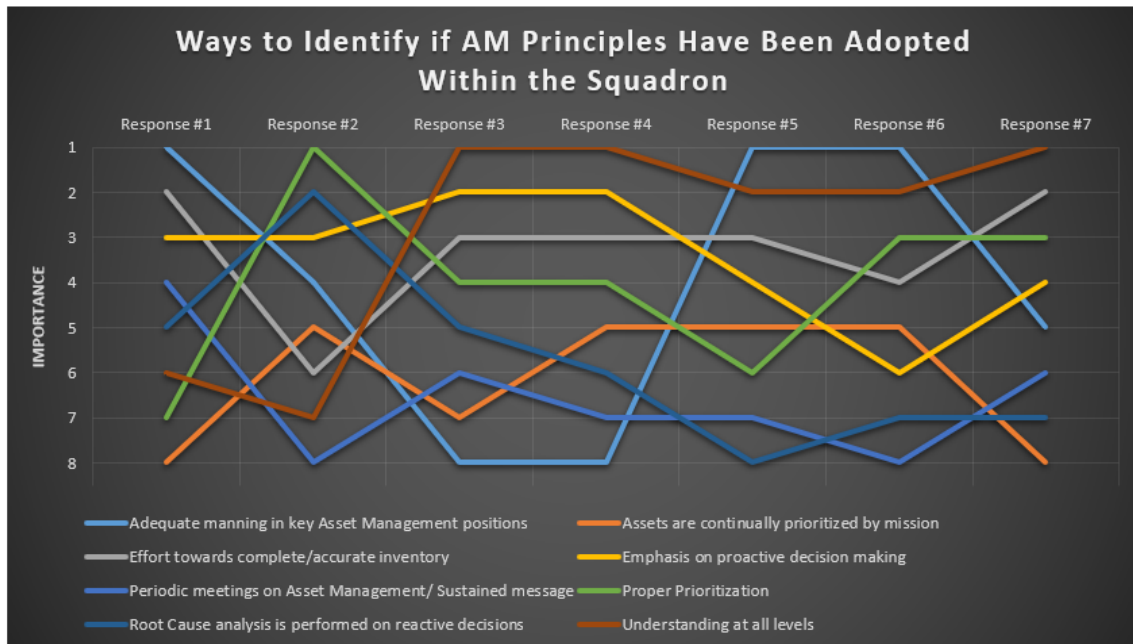


Figure 5.4: Round Two, Question 7 Graph

5.3.2.8 Question 8.

In round two question 8, the top ranked theme for the top ways an organization can ensure that its asset management efforts are continuously improving was a commitment to quality data. Figure 5.5 shows a graphical representation of the responses to round two, question 8. In round one, the top suggested theme for the top ways an organization can ensure that its asset management efforts are continuously improving was reflection and review of the data. While the two rounds were not identical this consistent emphasis underscores the importance of data to asset management.

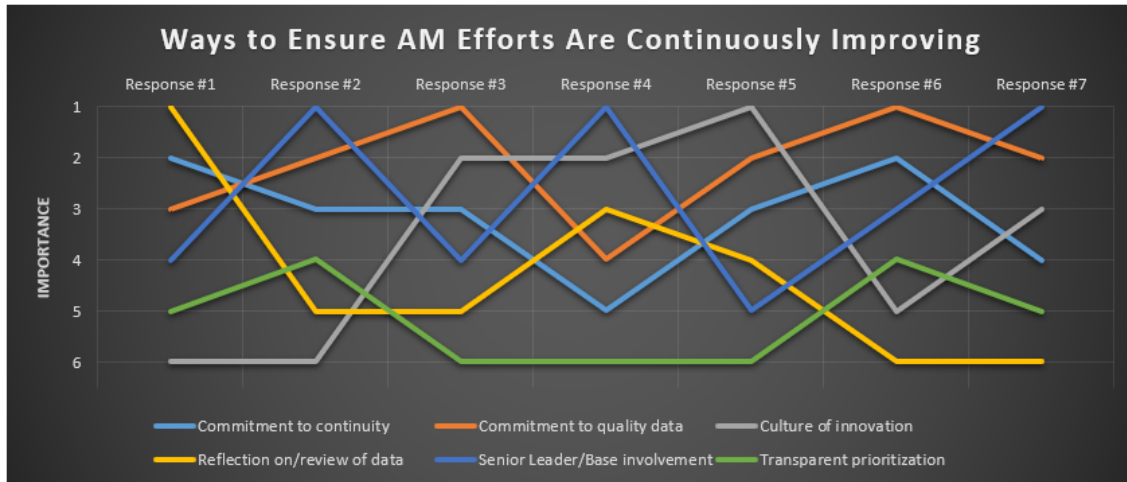


Figure 5.5: Round Two, Question 8 Graph

5.3.2.9 Question 9.

In round two question 9, the top ranked theme for the best indicators that an organization is effectively applying asset management principles was an improvement on existing measures of performance. Figure 5.6 shows a graphical representation of the responses to round two, question 9. In round one, the top specific theme for the best indicators that an organization is effectively applying asset management principles was improving system performance measures. This consistent emphasis underscores the importance of using and tracking existing performance measures.

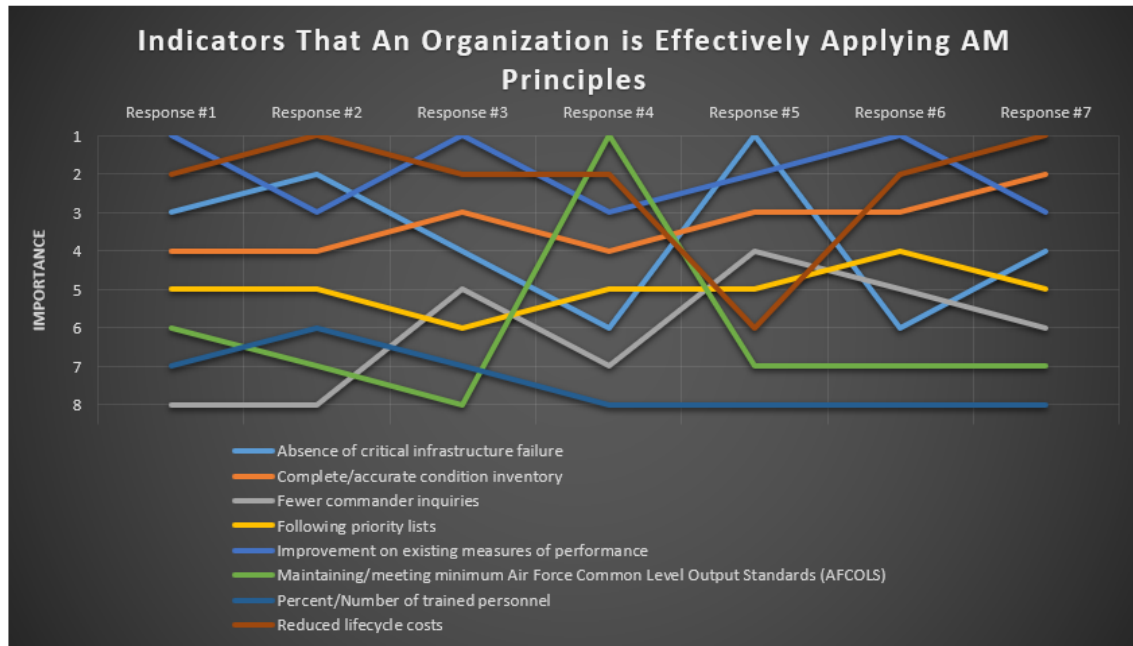


Figure 5.6: Round Two, Question 9 Graph

5.3.2.10 Question 10.

In round two question 10, the top ranked theme for ways that the Air Force should measure success in asset management was whether or not the data was used to inform decisions. Figure 5.7 shows a graphical representation of the responses to round two, question 10. In round one, the top specific theme for ways that the Air Force should measure success in asset management was the difference between planned and actual work or investments performed. While not identical answers, the central theme between rounds one and two were that successful asset management organizations should be following the recommendations of the data analytics tools

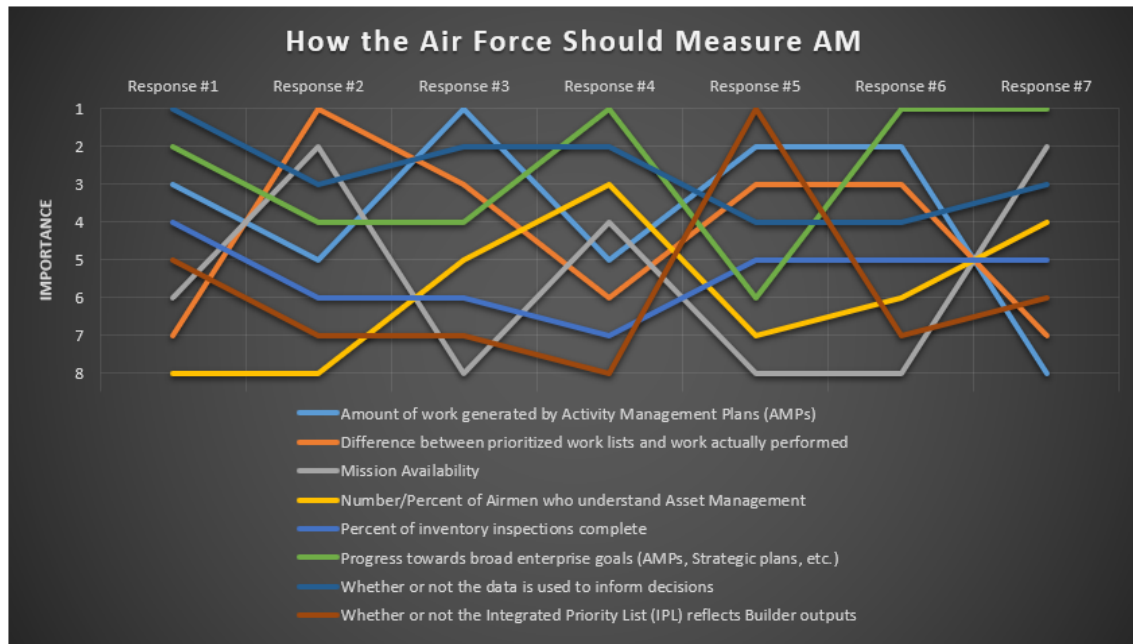


Figure 5.7: Round Two, Question 10 Graph

5.3.2.11 Question 11.

In round two question 11, the top ranked theme for elements of Air Force asset management philosophy that bases should commit to regardless of cost or effort required was enabling the base's mission. Figure 5.8 shows a graphical representation of the responses to round two, question 1. In round one, the top specific theme for elements of Air Force asset management philosophy that bases should commit to regardless of cost or effort required was a complete asset inventory.

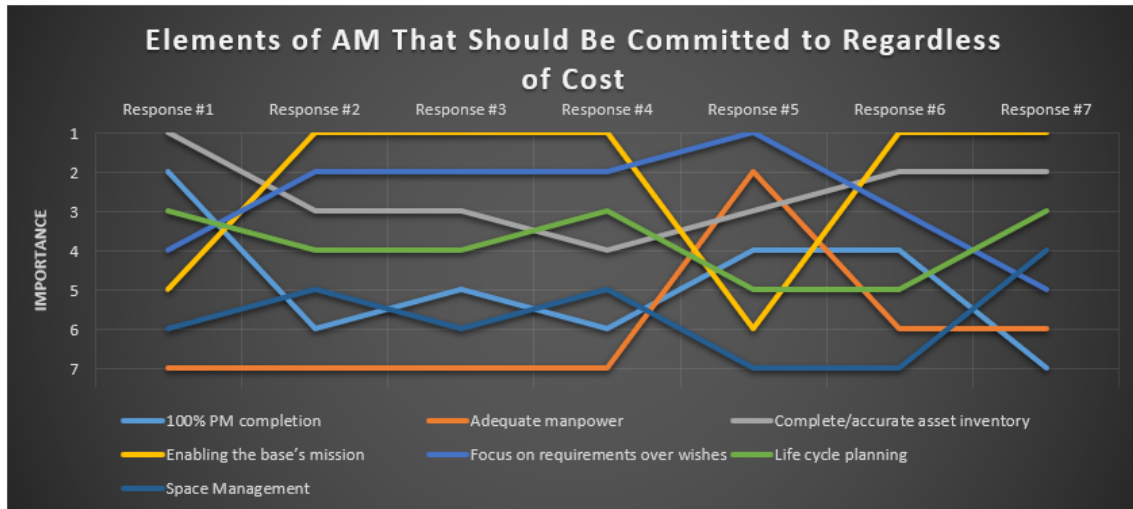


Figure 5.8: Round Two, Question 11 Graph

5.3.2.12 Question 12.

In round two question 12, the top ranked theme for the most critical behaviors/mindsets to success in asset management was buy-in. Figure 5.9 shows a graphical representation of the responses to round two, question 12. In round one, the top specific theme for the most critical behaviors/mindsets to success in asset management was split between shared understanding, buy-in, and critical or innovative thinking. Understanding is usually the first step to buy-in, so these results emphasize the need for the Air Force to first understand why asset management matters in order to achieve buy-in to asset management principles.

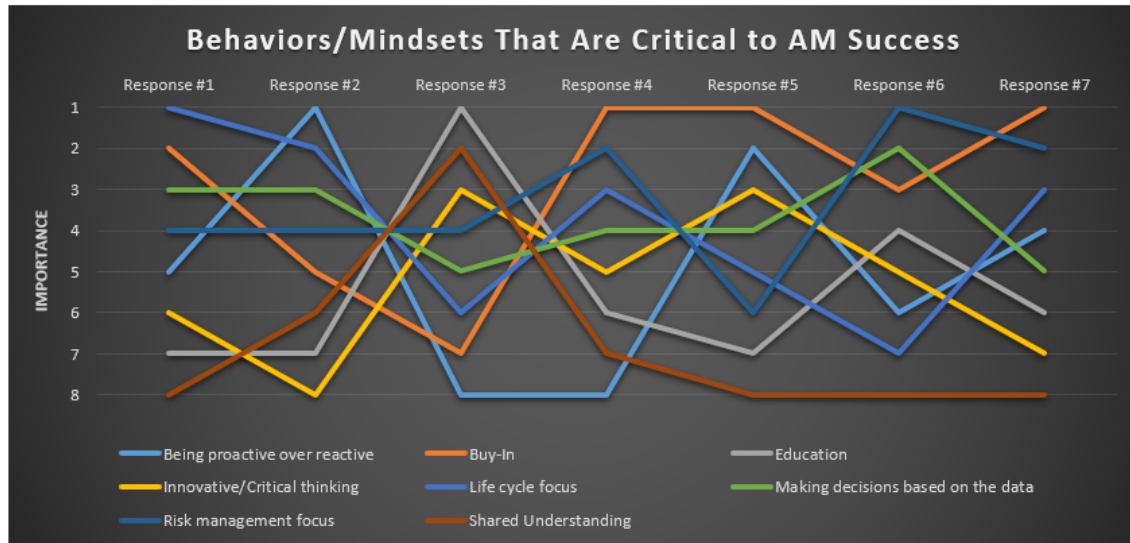


Figure 5.9: Round Two, Question 12 Graph

5.3.3 Round Three.

Round three of the Delphi technique questionnaire asked SMEs to indicate their level of agreement (or disagreement) with rankings that had been aggregated from round two responses. Analysis of round three responses will review the correlation of rankings between respondents, and the average ranking per question. It is important to remember during analysis of the collected data, that rankings of importance are relative to the other themes. Each theme that respondents were asked to rank were originally suggested as answers to questions in round one of the Delphi technique questionnaire. As such, if a theme has been ranked “least important”, that does not mean that the theme is not important at all as a response to the question, rather it means that the other themes are relatively more important.

The researchers used the following agreement ranking system: a response of “strongly disagree” was recorded as a 1; “disagree” was recorded as a 2; “neither agree nor disagree” was recorded as a 3; “agree” was recorded as a 4; and “strongly agree” was recorded as a 5. For the purposes of this analysis, an averaged ranking less than 2.5 indicated the SMEs do

not agree with the ranking as a whole. An averaged ranking between 2.5 and 3.5 indicated that the SMEs were unable to come to a consensus and neither agree or disagree with the ranking as a whole. An averaged ranking above 3.5 indicated general agreement and support for the aggregated ranking. Finally, an averaged ranking above 4.5 will indicate strong support for the aggregated ranking.

5.3.3.1 Question 1.

Round three question 1 asked respondents to indicate their agreement with rankings for the most important themes for successful asset management. The average agreement rating between the seven respondents on the provided ranking was 3.714, which indicated general support for the ranking of the top themes for successful asset management. Therefore, the data showed that the SMEs generally agree that leadership buy-in was the most important theme for successful asset management.

5.3.3.2 Question 2.

Round three question 2 asked respondents to indicate their agreement with rankings for ways the most effective ways to know that an organization is doing asset management well. The average agreement rating between the seven respondents on the provided ranking was 4.428, which indicated general support for the ranking of the top ways for an individual to know that they were doing asset management well. Therefore, the data showed that the SMEs generally agree that meeting defined performance standards was the most important theme for successful asset management.

5.3.3.3 Question 3.

Round three question 3 asked respondents to indicate their agreement with rankings for the most effective ways to communicate asset management principles to leadership. The average agreement rating between the seven respondents on the provided ranking was 4.714, which indicated strong support for the ranking of the most effective ways to communicate asset management principles. Therefore, the data showed that the SMEs

strongly agree that understanding *WHY* organizations should perform asset management was the most effective way to communicate asset management principles to senior leadership.

5.3.3.4 Question 4.

Round three question 4 asked respondents to indicate their agreement with rankings for the most effective ways to identify whether or not asset management principles have been broadly adopted within the squadron. The average agreement rating between the seven respondents on the provided ranking was 4.571, which indicated strong support for the ranking of the ways to identify whether or not asset management principles have been broadly adopted within the squadron. Therefore, the data showed that the SMEs strongly agree that understanding at all levels, was the most effective way to identify if asset management principles have been broadly adopted within the squadron.

5.3.3.5 Question 5.

Round three question 5 asked respondents to indicate their agreement with rankings for the most effective ways to ensure that an organization's asset management efforts are continuously improving. The average agreement rating between the seven respondents on the provided ranking was 3.428, which suggested that the SMEs were unable to come to a consensus about the top ways an organization can ensure that asset management efforts are continuously improving. However, a review of the disagreements with the ranking provide a better understanding. Two of the three disagreements centered around the importance of a culture of innovation, but did not mention any issues with the top three rankings. The other disagreement with the ranking indicated that senior leader and base involvement should be ranked as most important, rather than second most important. With regards to the respondents that did not disagree with the ranking, three respondents indicated agreement with the ranking, and two respondents indicated a strong agreement with the ranking. No respondents indicated that they neither agree nor disagree with the ranking. Based on the

agreement ranking and the commentary for disagreements, the researchers infer that the SMEs would generally agree that a commitment to quality data and senior leader/base involvement were important for ensuring that asset management efforts were continuously improving.

5.3.3.6 Question 6.

Round three question 6 asked respondents to indicate their agreement with rankings of the best indicators that an organization is effectively applying asset management principles. The average agreement rating between the seven respondents on the provided ranking was 4.285, which indicated general support for the ranking of the best indicators that an organization was effectively applying asset management principles. Therefore, the data showed that the SMEs generally agree that improvement on existing measures of performance was the best indicator that an organization was effectively applying asset management principles.

5.3.3.7 Question 7.

Round three question 7 asked respondents to indicate their agreement with rankings for the most effective ways that the Air Force should measure success in asset management. The average agreement rating between the seven respondents on the provided ranking was 3.143, which suggested that the SMEs were unable to come to a consensus about the ranking of the ways that the Air Force should measure success in asset management. A review of the disagreements with the ranking provide a better understanding of the dissent.

The respondent who strongly disagreed with the ranking indicated that mission availability should be ranked #1 instead of #6. However, a review of the round data shows that none of the respondents to round two thought that mission availability was the most important measure for success. Two round two respondents thought that mission availability was 2nd most important, with one round two respondent ranking the difference between prioritized and actual responses higher, and the other round two respondent

ranking progress towards enterprise goals higher. After reviewing the email records, it became evident that the one round three respondent that strongly disagreed with the ranking did not provide a response to the round two questionnaire. This opinion is valid, but the researchers must note that while a metric that reports mission availability may be relatively easy to calculate, it may be difficult to isolate the effect that asset management plays on it. This because there are many other factors outside of asset management and outside of CE control that have a direct impact on mission availability.

Both of the two respondents that disagreed with the ranking indicated that whether or not the IPL reflects BUILDER outputs should be ranked much higher. One of the two said that this should be #1, and the other indicated that it should just be closer to the top. Referencing the individual rankings, six of the seven respondents to round two indicated that the IPL reflecting BUILDER outputs was in the bottom half of relative importance.

Based on the provided agreement ratings in round three of the Delphi technique questionnaire, there were no clear recommendations for ways that the Air Force should measure asset management. Additional research is required.

5.3.3.8 *Question 8.*

Round three question 8 asked respondents to indicate their agreement with rankings for the elements of asset management philosophy that should be committed to regardless of cost or effort required. The average agreement rating between the seven respondents on the provided ranking was 4.429, which indicated general support for the elements of asset management philosophy that bases should commit to regardless of cost or effort required. Therefore, the data shows that the SMEs generally agree that enabling the base's mission was the element of asset management that bases should commit to regardless of cost or effort required. This certainly is the most important aspect of a Civil Engineer's mission, but is not necessarily an asset management philosophy in and of itself. Rather, it could be seen as a strategic goal and outcome of successful Air Force asset management. Based on

the provided ranking, a complete and accurate asset inventory, which is in fact a central philosophy of asset management, was the next most important philosophy. With this in consideration, the researchers would infer that the SMEs would generally agree that a complete and accurate asset inventory was a very important element of Air Force asset management, that should be committed to regardless of cost or effort required.

5.3.3.9 Question 9.

Round three question 9 asked respondents to indicate their agreement with rankings for the most critical behaviors/mindsets to success in asset management. The average agreement rating between the seven respondents on the provided ranking was 4.571, which indicated strong support for the most critical behaviors/mindsets to successful asset management. Therefore, the data shows that the SMEs strongly agree that buy-in was the most critical behavior/mindset to successful asset management. This priority was also supported by the response to question 1 of round three.

5.4 Answers to Research Questions

This section seeks to consolidate all of the findings from the three rounds of the Delphi technique questionnaire in order to answer the four research questions.

5.4.1 Research Question 1.

How should success in Asset Management be objectively defined and quantified?

The explicit findings from this present research effort do not provide a definite positive answer to this question. However, the results do not prohibit asset management from being objectively defined and quantified. If the Air Force SMEs had shared both a common understanding of asset management and a shared prioritization of asset management principles, the researcher feels that the questions submitted through the Delphi Technique would have been sufficient to answer research question 1. The rest of the section devoted to summarizing the answer to this research question seeks to overcome the differences in

understanding, as well as provide some of the researcher's suggestions for how success in Asset Management might be objectively defined and quantified.

It is the researchers' opinions that a large part of the difficulty in this study stems from the Air Force not establishing a comprehensive definition for asset management. Furthermore, as indicated by the responses to round one, question 1, the SMEs have very different understandings of asset management. Without a clear understanding of what asset management is, it can be difficult to define what successful asset management looks like. Based on the responses and the available research, the research team would suggest the following comprehensive definition for asset management in the Air Force: "The deliberate and ongoing process of managing an asset throughout its entire lifecycle by understanding its physical attributes, condition, usage, performance, importance, and environment; while optimizing risk acceptance, financial constraints, future plans, and strategic organizational objectives. However, even with this definition, it would be difficult to define success with just one metric. The following paragraphs discuss some elements that could be used to measure different aspects of success in asset management.

One of the primary goals of asset management is achieving cost savings and increasing efficiency. To this end, the Air Force might develop some metrics to indicate financial success. One potential financial measure could involve comparing actual operations and maintenance costs at a specific location with a pre-established baseline. While this comparison may be viable for a single location, it would prove problematic when trying to compare performance between bases. The primary challenge with this baseline comparison is that different bases have a diverse range of sizes and missions, not to mention varied facility types, ages, and environmental conditions, which might make direct comparison between bases difficult. A secondary challenge could arise if bases were compared to their own baseline. Although evaluating an individual base against its own baseline would ensure a fairer comparison, this method would not differentiate between bases that are already

doing a good job with less room for improvement than bases that are doing a far poorer job. Another methodology for developing a financial success metric might be to evaluate each facility's cost per year against an Air Force-wide average annual cost for each facility's type. This methodology would help to highlight facilities that deviate from the average (either positively or negatively), but would also likely face challenges in normalizing the cost data by location and facility size. Better methodologies for establishing financial success measures may exist within industry, but may be overcome by the military practice of completely spending the available budget to ensure that future funds are available, not to mention any end of fiscal year surplus spending, which would certainly skew cost reporting. All of these reasons make it difficult to develop a fair measure for financial success at each base.

Another potential measure for success would be the absence of facility failure. The Air Force could develop a metric that tracks the number of times that a facility has failed over a period of time. This of course would necessitate the Air Force establishing criteria for what facility failure means. Because of the different aspects of a facility performance, a facility might be considered to have failed when: it is unsafe for occupants, a major system has ceased to work, or the facility otherwise does not enable its occupants to perform their assigned mission. Bases could then be evaluated on the number of 'failure' days that they experience over the course of a year. This might be considered fairer, because although larger bases might have more opportunities for failure (more facilities), they also likely have more personnel and larger budgets to fix or prevent failures than smaller bases. In any case, this metric is limited because it only defines success as the absence of failure, but cannot differentiate between bases that are meeting the minimum standard of zero failures, and those that are truly excelling at asset management and have zero failures. If the Air Force were to take a long-term view of facility failure, a metric could be established that compares how long a facility remains operational and functional compared to its design

lifecycle or Air Force created standard lifecycles. This metric could be fairly evaluated when a facility is demolished, since the ultimate lifecycle of a facility is unknown until that point. This concept might provide a useful benchmark at an Air Force enterprise level, where there are larger quantities of demolished facilities at a single time, but may be too far reaching to evaluate at an individual base level, where there are far fewer facilities being demolished each year.

Another metric for success suggested by the SMEs is how much work is being generated by sub-AMP managers through the AMP process. This concept is based on the premise that units committed to asset management principles would be more proactive about identifying requirements before a facility needs repair or replacement. While proactive asset management minded units might generate more work, it is equally likely that creating a metric that measures the amount of work generated through the AMP process might incentivize units to create duplicate or unnecessary work requests, in order to score better on the metric. A similar, but potentially less problematic, metric for success would be to determine how well a unit's projected work list (created through sub-AMPs and BUILDER data) matches the actual work performed. This might encourage bases to strive for better work forecasting, while discouraging bases from addressing emerging requirements. Another potential difficulty with this type of measure is the length of time over which the projected and actual work is being compared. For example: it might be difficult to accurately and completely forecast requirements a year in advance, but comparing projected and actual work on a monthly basis might be prove too cumbersome to administer.

As highlighted in the discussions above, creating comprehensive metrics for asset management success can be fraught with difficulties and hidden challenges. Consulting the ISO 55000 confirms that evaluation of asset management is “indirect and complex”[12]. The ISO does however suggest that any asset management performance measures should

be directly tied to the organizational objectives[12]. Since the Air Force does not have a SAMP or any document that clearly outlines asset management objectives, it will be difficult to create effective performance metrics that measure progress towards these goals. An interim solution, until asset management goals are officially established could be to expand the use of the AFCOLS system to establish condition rating-based criteria and standards for facilities. Another suggestion would be for the Air Force to work towards growing asset management maturity at all levels, as recommended by ISO 55002 and many industry sources [18, 21, 23, 64, 86]. Enhancing asset management maturity should be considered an important step regardless of which maturity criteria is selected. Without an underlying asset management maturity and shared understanding, it is very likely that any performance measures could be ‘gamed’ so that units score well without actually doing well.

Table 5.1: Summary of Findings: Research Question One

Recommendations	
1	Establish a comprehensive and consistent definition for asset management
2	Establish a metric that evaluates bases on the number of ‘failure days’ that the base’s facilities experience
3	Establish a metric that compares a facility’s design life with its actual life
4	Establish a metric that evaluates how well a unit’s projected work list matches the actual work performed
5	Expand Air Force Common Output Level Standards (AFCOLS) to establish minimum condition ratings based on types of facilities
6	Assess asset management maturity for individual organizations

5.4.2 Research Question 2.

What are the key components of success in Asset Management?

Although it may be difficult to establish overarching metrics for success in asset management, this research effort has shown that there are a number of key components that help contribute to a holistic success in asset management. Each of these components should be seen as focus areas that will almost certainly promote Air force organizational objectives once they have been established.

The first key component to success in asset management is a complete and accurate asset inventory. Asset management centers around making both lifecycle and data informed decisions. A complete and accurate inventory is the foundation for the ability to make lifecycle and data informed decisions. If an organization is attempting to develop an investment strategy that focuses on fixing the facilities with the lowest condition scores, the optimal lifecycle and data informed decision can only be made if the organization truly knows the actual condition of every facility. These conditions are recorded through inspections and aggregated in the organization's asset inventory. As previously discussed, there are different types of condition inspections with varying degrees of detail and usefulness for developing a complete and accurate inventory. The Air Force should understand that doing a 'distress' method condition inspection will always lead to more accurate decision making [60]. Furthermore, it is imperative that the actual inspection process is performed consistently and objectively. The researcher's own experiences also indicate that there are some instances where having complete but unreliable data is actually worse than only having partial data that is accurate and reliable.

The second key component of success in asset management is consistent support from leadership through adequate resources and policy. Both this research effort and available asset management literature confirm that leadership buy-in is one of the most important determinants for a successful asset management program [9, 12, 18, 20, 23, 62, 86–91].

The Air Force has different types of leadership at many different levels, and it is important for all leaders to understand and support asset management. Support from leadership might take the form of recognizing that the most visible projects might not be the most important one. Support from leadership might take the form of not penalizing units that fail to spend their entire budget because those units are focused on making the most fiscally responsible decisions. Support from leadership might also take the form of prioritizing and emphasizing complete and accurate data collection efforts to the detriment of other activities. The results of this research effort also suggest that helping leaders understand why the Air Force is doing asset management is central to securing support from leadership. Regardless of the form of leadership support, it is unlikely that the rank and file of any organization will be able to fully adopt asset management principles unless the words of the leader advocating for asset management are fully backed up by their actions and the actions of their subordinates.

A third key component of asset management success is using data to make decisions, rather than making decisions on purely subjective prioritization. To a large extent, the Air Force is already implementing this concept by making condition scores a key part of the IPL funding model. This key component is tied to both an accurate asset inventory and support from leadership. As previously discussed, an organization will be unable to make optimal asset management decisions if it does not have accurate data. Senior leadership's support and understanding of asset management is also important when the leadership has to rely on the scoring model and asset management process rather than on their own personal preferences.

A fourth key component of success in asset management is developing and practicing a lifecycle focus. A lifecycle focus means that decision makers understand that in many cases, spending some money in the short term can save even more money in the long term. This can be a challenge in many industries, but especially in the Air Force, where budgets

are built and executed on the basis of a single year. Leaders can show their support for this lifecycle focus by advocating for any additional funds that are necessary for making better long-term decisions. A lifecycle focus is also incredibly important during construction efforts. Research has shown that over a period of 30 years, a buildings operating costs can be three times as much as the original construction costs [92]. By keeping a lifecycle focus during construction, Air Force decision makers might choose options that have higher initial construction costs, but have lower maintenance costs or requirements during the long term, as is common in ‘green’ and sustainable construction.

The final key component of successful asset management is proactive decision making. Asset management mindsets coupled with financial principles suggest that there is an optimal time to repair facilities and equipment, that both minimizes costs and maximizes the extension of useful life for the asset. Conversely, reactive decision making paradigms repair equipment or facilities when they are broken or no longer useful. This reactive mindset is inefficient, because the cost to fix a failed system is almost always more than the cost to repair a degraded system. Beyond the cost aspect, failed equipment or facilities can also create dangerous conditions that would not be present in equipment or facilities that are only damaged. Proactive decision making allows Air Force civil engineers to apply asset management principles and fix problems before they become more expensive or hazardous.

Table 5.2: Summary of Findings: Research Question Two

Recommendations	
1	Prioritize complete and accurate data across the enterprise
2	Focus on securing leadership buy-in of asset management across organizational levels and functional disciplines
3	Emphasize the need to make decisions based on data, as opposed to trying to adapt data to support decisions that have already been made
4	Foster lifecycle thinking at all levels of decision making
5	Foster proactive actions over reactive responses

5.4.3 Research Question 3.

How can successful Asset Management principles benefit the CE community?

The SMEs consulted in this research effort enumerated many benefits that successful asset management principles can provide to the CE community. First, asset management principles have helped reduce lifecycle costs for many industry practitioners. The large size of the Air Force enterprise means that any prospective reductions in cost would be substantial in nature. Another benefit of applying asset management principles within the CE community is an increased ability to support the mission of the Air Force. By leveraging accurate asset condition data and predictive analytics, Civil Engineers will be better equipped to respond to degraded infrastructure before it becomes an emergency. Fewer emergencies mean that there will be fewer interruptions to the mission.

Another benefit of asset management principles is that accurate asset inventories can help civil engineers predict and plan future requirements. This enhanced prediction ability can help civil engineers advocate for necessary resources in advance and plan future

budgets with greater accuracy. By developing more accurate budgets, civil engineers will be better equipped to handle limited resources and shrinking budgets.

Finally, asset management principles can help the CE community by reducing uncertainty about the status, type, and condition of assets. This reduced uncertainty helps to reduce risk and increase understanding of a base's actual real property inventory at all levels. Asset management principles can also help to illustrate and explain the risks involved with deferred maintenance or repairs. By understanding and leveraging these benefits, Civil Engineers can help achieve buy-in from leadership and share the effects of these benefits with the rest of the Air Force.

Table 5.3: Summary of Findings: Research Question Three

Benefits of Asset Management	
1	Reduced lifecycle costs
2	Increased ability to support the mission
3	Increased ability to anticipate and plan for future requirements
4	Reduced uncertainty about assets

5.4.4 Research Question 4.

How can success in Asset Management be communicated and encouraged within the CE community?

The results of this research effort provide many different ways that asset management might be communicated and encouraged within the CE community. First and foremost, the opinions of the SMEs indicate that the top ways to communicate asset management principles are helping leaders to understand why asset management is important, illustrating risk, and using mathematical scoring models to show asset management

effectiveness. Beyond that, the SMEs also emphasize the importance of having higher levels of Air Force leadership communicate asset management principles to their peers and subordinates.

With regards to encouraging asset management within the CE Community, responses from the SMEs and the personal experiences of the researchers indicate that the primary incentive is additional funds for a unit or base. If these incentive funds are awarded to the Wing Commander and were discretionary in nature (with no strings attached), Civil Engineers would likely receive more support for making the right asset management decisions. While it is perfectly viable for higher headquarters to earmark specific funds for these financial incentives, they might also choose to distribute surplus end of year funds to organizations with the best asset management programs. In doing so, these higher headquarters would not need to look for additional funding outside of their current budgets. On the opposite side of incentives, the SMEs suggest that the primary way to discourage negative behavior in the Air Force is through inspections. As suggested by the SMEs, if Wing Commanders are graded and inspected on the effectiveness of the base's asset management ability, then Wing Commanders might be more likely to provide support for asset management efforts. Furthermore, by making asset management inspectable at the Wing level, there would likely be fewer conflicts of priority between Civil Engineers and other base leaders.

The previous paragraph highlighted the ways to encourage good asset management performance and discourage bad asset management performance within existing systems. Additionally, SMEs provided some innovative suggestions to encourage asset management performance that currently do not exist within the Air force. At an individual level, the SMEs suggested that asset management principles could be evaluated on annual appraisals and/or the CE community could create new awards or recognition to reward successful asset managers. At an organizational level, the SMEs reiterated the value in awards, recognition,

and discretionary funds. Beyond individual and organizational awards, the SMEs also suggested that higher headquarters might be able to set aside or otherwise designate funds for future projects as requested in the BAMPs. In doing so, these higher headquarters would help reinforces the usefulness of the AMP process and create buy-in at the lowest levels. Finally, the SMEs reiterated that senior leadership would be able to demonstrate their support for and commitment to asset management principles by not reducing a unit's budget when it fails to spend all of its allocated annual funding.

Table 5.4: Summary of Findings: Research Question Four

Recommendations	
1	Help leaders understand why asset management is important
2	Explain asset management by illustrating risk
3	Utilize mathematical scoring models to explain asset management
4	Encourage top-down communication of asset management principles
5	Make discretionary funding incentives available for top asset management performers
6	Inspect Wing Commanders on the effectiveness of their asset management programs
7	Create individual and organizational awards to recognize asset management performance
8	Designate future funds for requirements identified in BAMPs
9	Remove penalties for not spending the entirety of a unit's budget

5.5 Implications for Practice

Over the course of this research effort, the researchers developed or discovered many different implications for practice within the asset management industry. The implications in this section are divided into three broad categories: suggestions from SMEs, implications from the research process, and implications from the results. The suggestions from SMEs section covers specific commentary from the SMEs that were provided in response to open ended questions, but does not directly answer the research questions. The general implications from the research process section covers those implications that were developed by the researchers over the course of the research and writing effort. Finally, the specific implications from research results section covers those implications that can be made directly from the results of the third round of the Delphi technique questionnaire.

5.5.1 Suggestions from SMEs.

Most of the suggestions from the SMEs are directly related to specific Air Force challenges and concerns. As such, these suggestions may only be beneficial for organizations with similar challenges. One of the first major suggestions from the SMEs is that the Air Force should take a hard look at how it writes and organizes its 'Air Force Instructions (AFIs). For context, AFIs provide guidance and rules that Air Force personnel must comply with. Feedback from one of the SMEs suggests that presently AFIs are organized around current organizations rather than core tasks. This SME suggests that since asset management is a mindset that transcends organizational hierarchies, AFIs should be task focused, in order to prevent 'stove piping'. It is the recommendation from this SME that the number of AFIs relevant to civil engineers could also be reduced with this mindset to create the following holistic AFIs: planning and programming, acquire and divest, operate and sustain, and protect and recover.

Following this line of thinking, another SME suggested that Air Force asset management could and should tie in better with mission and organizational objectives.

Based on available asset management literature, the researchers feel that the best way to tie in mission and organizational objectives would be through the development of an Air Force SAMP, as recommended by the ISO 55000 series. Another major suggestion from the SMEs is for the Air Force to investigate and implement measures for asset management maturity, also in line with the ISO 55000 series. This commitment to increasing asset management maturity is a necessary step to ensure that Air Force asset management efforts are continuously improving.

The next major suggestion from one of the SMEs would be to bolster the AFCOLs process in a way that aligns the shared goals of installation management and other mission partners on the base. Another SME, who highlighted the importance of buy-in to asset management, suggested that while support from leadership is important, it is actually buy-in from the lower levels of shop leadership that has a direct correlation with asset management success.

Another major suggestion from the SMEs was to investigate the metrics that the Air Force Personnel Center uses to evaluate their management of human capital. This SME suggests that the personnel center is judged on the percentages of actual assignments that are consistent with an Air Force member's personal desires and development plans. Although this is beyond the scope of this research, this could potentially provide a starting place for those trying to develop a metric that compares planned work and actual work performed.

The final major suggestion from the SMEs is that the Air Force should invest in developing both accurate predictive analytics and extensive cost databases. By effectively using information from databases, the Air Force engineer would be better able to use asset management principles to accurately predict and plan for future requirements. There is some capability to perform this type of analysis within existing systems, but bolstering

analysis and predictive capabilities would allow for increasing amounts of utility and validity.

Table 5.5: Summary of Findings: Suggestions from SMEs

Recommendations	
1	Realign AFIs to follow core tasks instead of organizational hierarchies
2	Investigate and implement measures for asset management maturity
3	Robust the AFCOLS process to align the shared goals of both installation management and mission partners on the base
4	Investigate and potentially adapt the measures that the Air Force Personnel Center uses to evaluate their management of human capital
5	Invest in developing both accurate predictive analytics and extensive cost databases

5.5.2 General Implications from Research Process.

Throughout the research and writing process, the researchers developed three main implications for practice, that were not directly derived from the SMEs or the results of the Delphi technique. The first implication for practice would be to recommend the development of metrics that gauge not only the completeness of inspection data, but also the quality of the inspection data. This recommendation comes from the consistent emphasis on the importance of quality data to asset management, from other research, private industry, and this research effort. Through BUILDER, the Air Force's condition management system, bases are able to see and report the completeness of their real property inventory and how recently it has been inspected. For most organizations, it would be fairly easy to create metrics for how complete the data is, and how new the inspection records

are. For completeness, the metric could compare the number of complete records to the total number of records, creating a completion percentage. To measure and compare how recent the inspections are, an organization could create a metric that counted the number of instances that the most recent inspection is older than a certain age. Current Air Force policy dictates that no inspection should be older than five years [93], so this metric would help an Air Force base track their progress against this policy. However, if an organization wanted to move past compliance, a more robust metric would need to be developed. One suggestion for such a metric would be to find an average at a particular location for the amount of time since the most recent inspection, across all facilities. In order to measure the quality of the inspection data, each inspection type could be assigned a point value. The most detailed objective inspections should be given higher point values than less detailed subjective inspections. Once point values are assigned to each type of inspection, an average could be generated across the inventory. Organizations could take this inspection quality metric one step further by creating a size multiplier, that provides greater scores to detailed inspections of larger facilities than detailed inspections of smaller facilities. Through use of these inspection metrics, any organization, including the Air Force, could find ways to foster asset management success through a commitment to quality data.

The next implication for practice dealt with fostering communication about asset management. Round one of the Delphi technique questionnaire highlighted that most SMEs were unaware of any Air Force units that were doing asset management well. To help resolve this issue, the researchers recommend that any organization who is striving for asset management success, find and share examples of successful asset management. Examples of success could come from case studies, research, news articles, or examples internal to the organization. The group or organization that is in charge of driving asset management should then ensure that these examples are made both available and known to personnel within the organization. For the Air Force, this would mean that AFCEC

could send out regular newsletters with examples of successful asset management and that AFCEC leaders should acknowledge asset management success, especially when it comes from within the Air Force. Communication of what works and what is important should be used to create inspiration and a common understanding of what asset management success looks like.

The final implication for practice is fairly common sense, but still incredibly important. The researchers recommend that every organization spend time identifying and evaluating the unique strengths and weaknesses of their organization related to asset management. No two organizations are the same, which suggests that no two asset management programs should be identical. Many organizations may be in tune with their limitations and constraints, but it is important to also consider the unique strengths of that organization. Through the Delphi technique, researchers were able to solicit strengths and weaknesses from SMEs. These strengths and weaknesses were then analyzed to develop a deeper understanding of the Air Force environment. Through leveraging an organization's unique strengths and weaknesses, that organization will be better able to develop an effective and unique asset management program.

Table 5.6: Summary of Findings: General Implications from Research Process

Recommendations	
1	Develop metrics to gauge the completeness and quality of condition inspection data
2	Foster increased communication about asset management within the Air Force
3	Identify and evaluate the unique strengths and weaknesses of individual organizations with respect to asset management

5.5.3 Specific Implications from Research Results.

This final section of implications for practice deals directly with the results of round three of the Delphi technique questionnaire.

The data from question 1 showed that the SMEs generally agree that leadership buy-in was the most important theme for successful asset management. Leadership buy-in is difficult to measure, but incredibly important. The researchers recommend that AFCEC partner with the CE schoolhouse at the Air Force Institute of Technology to ensure that asset management education is made more readily available for leaders as well as practitioners.

The data from question 2 showed that the SMEs generally agree that meeting defined performance standards was the most effective way of determining that an organization is doing asset management well. This information is useful, but may prove to be slightly recursive in nature when taken on its own. The researchers suggest that this data should be used to emphasize the importance of developing performance standards. If performance standards are carefully created to minimize unintended consequences, and aligned with organizational objectives (through a SAMP), then these performance measures will help indicate and encourage successful asset management.

The data from question 3 showed that the SMEs strongly agree that understanding *WHY* organizations should perform asset management was the most effective way to communicate asset management principles to senior leadership. The researchers suggest that these results reaffirm the need for communication and training for Air Force leaders. Communication could be encouraged through the asset management newsletters discussed in the general implications from the research process section. Training that helps leaders understand why an organization should perform asset management could be accomplished through previously mentioned education opportunities.

The data from question 4 showed that the SMEs strongly agree that understanding at all levels, was the most effective way to identify if asset management principles have

been broadly adopted within the squadron. Understanding at all levels can be achieved through experience practicing asset management principles, communication about what successful asset management looks like, consistent messages and policies from leadership, and aforementioned education opportunities.

The data from question 5 led the researchers to infer that the SME's would generally agree that a commitment to quality data and senior leader/base involvement were important for ensuring that asset management efforts are continuously improving. Commitment to quality data could be demonstrated to units through sustained messages from leaders, and the development of policies that encourage this commitment. Commitment to accurate data could be measured through the data quality metrics that were previously discussed in the general implications from research effort section. Senior leader and base involvement could be cultivated through communication efforts that help non-engineers understand why asset management is important, and how the asset management program is actually executed.

The data from question 6 showed that the SMEs generally agree that improvement on existing measures of performance was the best indicator that an organization is effectively applying asset management principles. Much like the data from question 2, the researchers suggest that the findings from question 6 reemphasize the importance of developing and using effective performance standards that are aligned with organizational objectives.

The data from question 7 suggested that there are no clear recommendations for ways that the Air Force should measure asset management. This inconclusive finding indicates that more research is required. Additionally, the researchers suggest that this lack of agreement between SMEs ultimately stems from different opinions on what aspects of asset management are most important to the Air Force. Furthermore, the researchers suggest that this disagreement could be lessened by the development of a SAMP for the Air Force.

The data from question 8 led the researchers to infer that the SMEs would generally agree that a complete and accurate asset inventory was a very important element of

Air Force asset management, which should be committed to regardless of cost or effort required. These results reaffirm the importance of quality data. The researchers suggest that metrics that asset management organizations measure and encourage quality data, as previously discussed in the general implications from the research section.

The data from question 9 showed that the SMEs strongly agree that buy-in was the most critical behavior/mindset to successful asset management. The researchers suggest that these results reaffirm the importance of communication and understanding, which help foster and encourage buy-in from an individual. Once again, the researchers suggest that communication and understanding can be achieved through educational opportunities, newsletters, and consistent messages from leadership.

Table 5.7: Summary of Findings: Specific Implications from Research Results

Findings About SME Agreement on Asset Management (AM) Principles	
1	SMEs generally agree that leadership buy-in was the most important theme for successful AM
2	SMEs generally agree that meeting defined performance standards was the most effective way of determining that an organization is doing AM well
3	SMEs strongly agree that understanding <i>WHY</i> organizations should perform AM was the most effective way to communicate asset management principles to senior leadership
4	SMEs strongly agree that understanding at all levels, was the most effective way to identify if AM principles have been broadly adopted
5	SME's likely agree that both a commitment to quality data and senior leader/base involvement were important for ensuring that AM efforts are continuously improving
6	SMEs generally agree that improvement on existing measures of performance was the best indicator that an organization is effectively applying AM principles
7	There is no clear agreement on how the Air Force should measure AM
8	SMEs likely agree that a complete and accurate asset inventory was a very important element of Air Force AM, which should be committed to regardless of cost or effort required
9	SMEs strongly agree that buy-in was the most critical behavior/mindset to successful AM

5.6 Limitations

This study has the following limitations:

1. Since the research team and the survey respondents work for the United States Air Force, the findings may have an application that is more relevant to the Air Force context. The Air Force is motivated and directed by mission and not by money, so the results of this research analysis may not be as applicable to private corporations. However, this shift in focus may make this analysis more applicable to other organizations within the Department of Defense, or even to other similar government agencies.
2. The data for this analysis is generated from responses to surveys. As a result, the data will be somewhat subjective and opinion based.
3. Since the surveys were only sent to pre-identified subject matter experts, the analysis will be limited in that it likely does not include every possible opinion from every possible background or level of experience.
4. The study is further limited by the fact that survey data was only collected from individuals that had both the time and desire to respond to the questionnaires.

Because this research effort only involved participants within the United States Air Force, the results and findings may not be externally valid outside of the Air Force. This lack of immediate external validity was considered to be acceptable, because this research effort is focused on solving an Air Force specific problem.

5.7 Recommendations for Further Research

For future research efforts, the author recommends several different opportunities to further develop asset management concepts. First, future researchers could work with AFCEC and other policy makers to draft a SAMP, as outlined by the ISO 55000 series.

In doing so, these researchers would help set up the framework to develop the strategic organizational objectives that are essential to developing practical metrics. Second, future researchers could expand the survey audience, to determine whether the opinions expressed by the SMEs are shared by other civil engineers, especially General Officers, Senior Executive Service employees, and Enlisted members. Third, future researchers could investigate the feasibility of adopting a more decentralized asset management program, similar to the one demonstrated by the Federal Highway Administration. As previously discussed, the Air Force has a rich diversity of missions, objectives, locations, and assets. Through decentralization, the Air Force might use MAJCOMs to develop asset management objectives that are tailored to their mission, but utilize the AFCEC to provide oversight for the process. Finally, future researchers might seek to develop practical metrics that evaluate how closely a CE squadron's projected work list matches the work list that is actually executed across the base.

5.7.1 Proposed Way Forward for the Air Force.

This research effort has produced many findings that the researcher believes would be of great benefit to the practice of asset management within the United States Air Force. However, the researcher understands that simply completing this thesis will not "fix" the Air Force's asset management implementation. In order to implement the findings and realize the potential of benefits of this research, the researcher recommends that the Air Force seek to accomplish the following five steps. First, CE leaders should attempt to organize an Air Force asset management summit that gathers the necessary asset management policy makers and practitioners for the purpose of improving Air Force asset management. Second, the organizers of the summit should seek to convince the attendees that there is in fact a problem with how the Air Force is currently implementing asset management. The findings of this research and the demonstrated lack of agreement shown in this study may prove very useful for illustrating the Air Force's problems with

asset management. Third, having agreed that there is a problem, Air Force leaders should designate a single office of responsibility for Asset Management policy and implementation. The current organizational hierarchy within the Air Force does not establish a single asset management authority, which can make policy updates incredibly complex and problematic. This single point of asset management authority might logically reside within the Air Force Civil Engineer Center, though it is not absolutely necessary that it does so. Fourth, this office of asset management responsibility should seek to create a Strategic Asset Management Plan, as recommended by the ISO 55000 series [12]. This SAMP should align the specific mission priorities of the Air Force with goals for the infrastructure that supports those priorities. While it is certainly possible for the Air Force to create a SAMP without outside help, the Air Force might benefit from the vast wealth of knowledge within the asset management consulting industry. Finally, after the SAMP has been established, the office of asset management responsibility should focus on rewriting relevant policy to support the SAMP, and increasing asset management education within the Air Force, most likely by leveraging the strengths of the Civil Engineer school and the Air Force Institute of Technology.

5.8 Conclusion

Asset management is a continuously developing field with great potential for the Air Force. Every organization is unique and as such, asset management programs must be tailored to specific organizational priorities, strengths, and weaknesses. This research effort solicited opinions from Air Force SMEs in order to develop an understanding of what success in Air Force asset management might look like. Some of the major findings of this study were the need to develop both a clear definition of what asset management is and an official SAMP for the Air Force. Other findings of this research effort included: the importance of leadership buy-in; complete and accurate facility inventory; and understanding of asset management principles at all levels of the organization.

Appendix A: Initial Email Text

“BLUF: You have been identified as a potential Asset Management SME. Your response to the attached AFIT research questionnaire is requested by 11 Aug 17.

Good Afternoon,

PURPOSE: You are receiving this email because you have been identified as a potential Subject Matter Expert in the field of Air Force Asset Management. I am a CE officer currently enrolled in the Graduate, Engineering Management (GEM) program at the Air Force Institute of Technology (AFIT). The focus of this thesis effort is to develop tangible and actionable measures of success for Asset Management. The sponsors of this research are CCd.

BACKGROUND: It is my experience that while most CE personnel / units / organizations are doing Asset Management as a process, many do not have a grasp on what the end state should look like, nor how to get there. To develop this field of knowledge, the research team is performing a Delphi Study in which the researcher attempts to find consensus amongst SMEs through several rounds of surveys. The first survey is attached.

SURVEY INFORMATION: Participation is completely voluntary and you may drop out at any time, with no adverse effects. The questionnaire is 19 questions long and you may write as much or as little as you wish. As you are able, please accomplish the attached survey by 11 August 2017. Further information about the study and questionnaire can be found in the attached survey. This PDF survey has a submit button which should work to attach and email the response. If that does not work, please respond directly to this email.

Please let me know if you believe that you have received this email in error. Additionally, if you have any questions or concerns, please let me know. Thank you very much for your time and consideration.”

Appendix B: Relationship Between Research Questions and Round One Questions

To establish the problems and context within Air Force Asset Management the researchers developed the following questions:

- What does Asset Management mean to you?
- What are the best people/organizations that you have seen do Asset Management well? What did they do well?
- How are you judged on effective Asset Management, and how does your boss rate your performance on it?
- What incentives do you have to do Asset Management well? How well do they work?
- What Air Force-unique limitations most hinder Asset Management success?
- What Air Force-unique advantages most promote Asset Management success?

To help determine how Asset Management should be objectively defined and quantified (Research Question #1), the researchers developed the following questions:

- How are you judged on effective Asset Management, and how does your boss rate your performance on it?
- How do you know if you are doing Asset Management well?
- How would you distinguish effective from ineffective Asset Management?
- What metric(s) do you believe best indicate that an organization is effectively applying Asset Management principles?
- How do you think the Air Force should measure success in Asset Management?

To help identify the key components of success in Asset Management (Research Question #2), the researchers developed the following questions:

- What are the key elements that make up Asset Management?
- What aspects of Asset Management help an organization succeed the most?
- What are the best people/organizations that you have seen do Asset Management well? What did they do well?
- How can you tell if Asset Management principles have been broadly adopted within the squadron?
- How can an organization ensure that its Asset Management efforts are continually improving?
- How would you distinguish effective from ineffective Asset Management?
- What metric(s) do you believe best indicate that an organization is effective applying Asset Management principles?
- How do you think the Air Force should measure success in Asset Management?
- What elements of the Air Force's Asset Management policies should bases commit to regardless of cost or effort required?
- What behaviors/mindsets are most critical to success in Asset Management?

To help answer how Asset Management principles can benefit the CE community (Research Question #3), the researchers developed the following questions:

- What are the results of poor Asset Management, and how would you assess/measure these?
- How can an organization ensure that its Asset Management efforts are continually improving?
- How do you think the Air Force should measure success in Asset Management?
- What elements of Asset Management are most important to the Air Force Civil Engineer enterprise?

- What elements of the Air Force's Asset Management policies should bases commit to regardless of cost or effort required?

To help answer how to communicate and encourage Asset Management success within the CE community (Research Question #4), the researchers developed the following questions:

- What incentives do you have to do Asset Management well? How well do they work?
- How have you seen Asset Management principles successfully communicated to leadership (Group/CC and above)?
- How can an organization ensure that its Asset Management efforts are continually improving?
- What elements of Asset Management are most important to the Air Force Civil Engineer enterprise?
- What Air Force-unique advantages most promote Asset Management success?

Appendix C: Correlation Plots

The correlation plots in this appendix are generated in RConsole, and compare each participants rankings with each other participant. A positive correlation indicated agreement between individuals. A correlation close to zero indicated that participants opinions were unrelated to one another, and a negative correlation indicated that individuals' priorities were opposed. Each correlation plot included in this research effort provides both a numerical correlation (below and left) and a graphical correlation (above and right).

C.1 Round 2

A correlation plot that compares all of the round two rankings is shown below in Figure C.1. The average agreement correlation is 0.39, which indicates a weak overall agreement. The strongest agreement correlation is 0.68, between participants four and seven, which indicates a strong agreement. The lowest agreement correlation is 0.10, between participants two and seven, which indicates that their opinions were fairly unrelated.

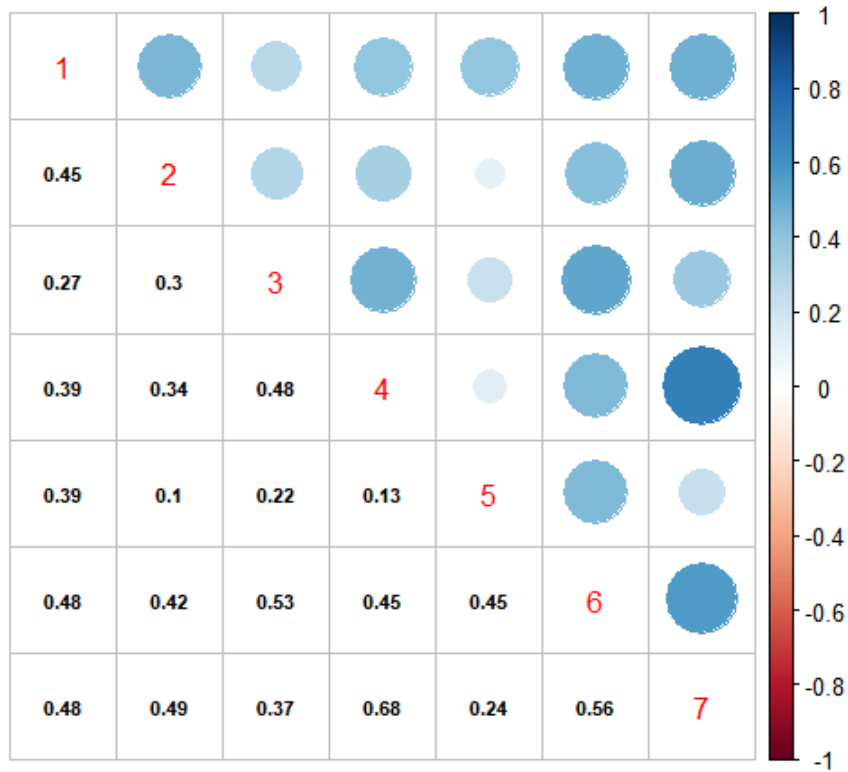


Figure C.1: Round Two Correlation Plot

C.1.1 Round 2 Question Plots.

A correlation plot that compares the round two, question 4 rankings is shown below in Figure C.2. The average agreement correlation is 0.38, which indicated a weak overall agreement. The strongest agreement correlation was 0.90, between participants two and seven, which indicated a very strong agreement. The lowest agreement correlation was -0.50, between participants three and five, which indicated a fairly strong disagreement.

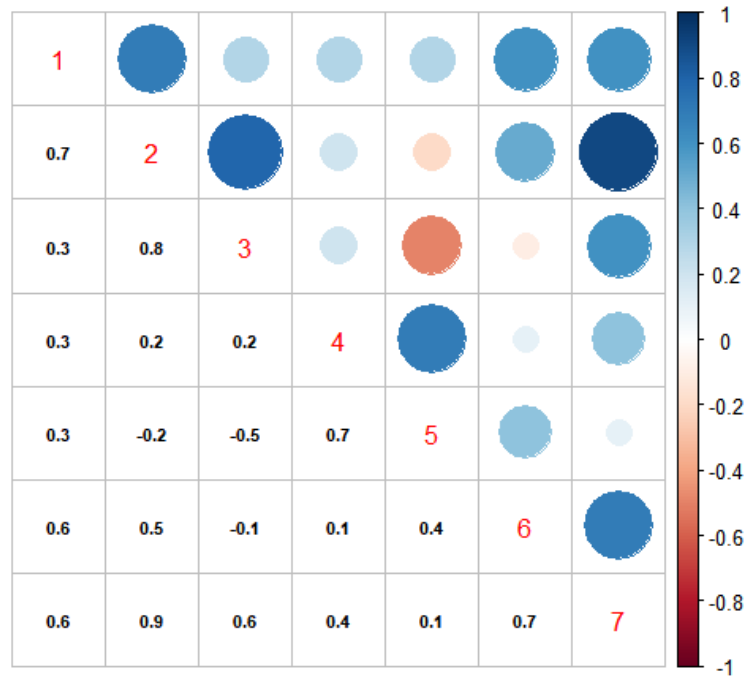


Figure C.2: Round Two, Question 4 Correlation Plot

A correlation plot that compares the round two, question 5 rankings is shown below in Figure C.3. The average agreement correlation was 0.40, which indicated a weak overall agreement. The strongest agreement correlation was 0.90, between participants one, three and four, as well as participants six and seven which indicated a very strong agreement. The lowest agreement correlation was -0.70, between participants two and five, which indicated a strong disagreement.

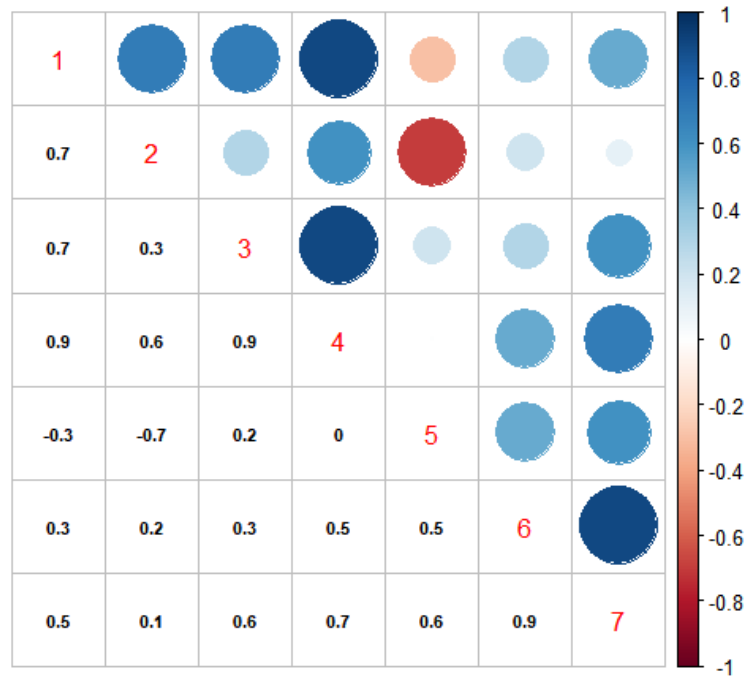


Figure C.3: Round Two, Question 5 Correlation Plot

A correlation plot that compares the round two, question 6 rankings is shown below in Figure C.4. The average agreement correlation was 0.33, which indicated a weak overall agreement. This data was somewhat skewed by the two SME's (four and five) that answered differently. The strongest agreement correlation was 1.00, between participants one, two, three, six and seven which indicated a perfect agreement. The lowest agreement correlation was -1.0, between participant five and participants one, two, three, six, and seven, which indicated a perfect disagreement.

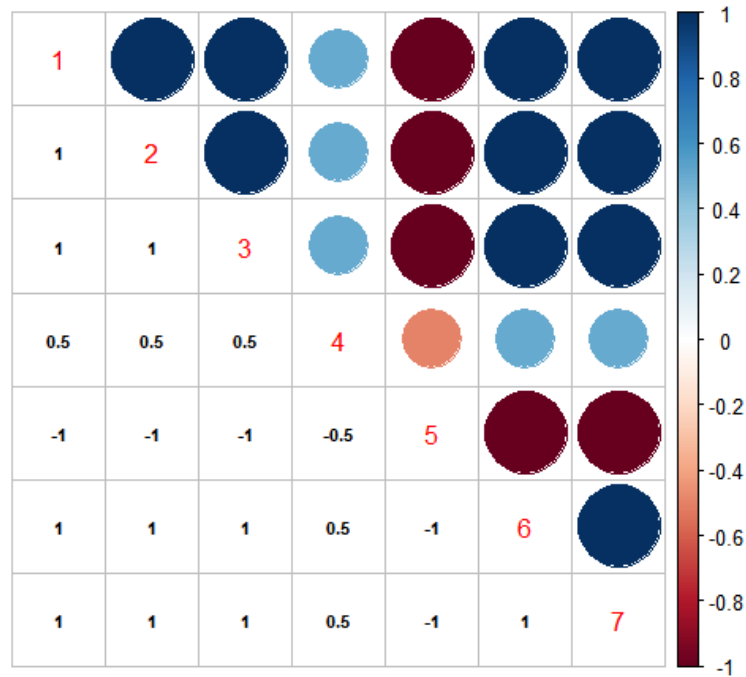


Figure C.4: Round Two, Question 6 Correlation Plot

A correlation plot that compares the round two, question 7 rankings is shown below in Figure C.5. The average agreement correlation was 0.23, which indicated a fairly weak agreement. The strongest agreement correlation was .93, between participants three and four, which indicated a very strong agreement. The lowest agreement correlation was -0.26, between participants two and five, which indicated a fairly weak disagreement.

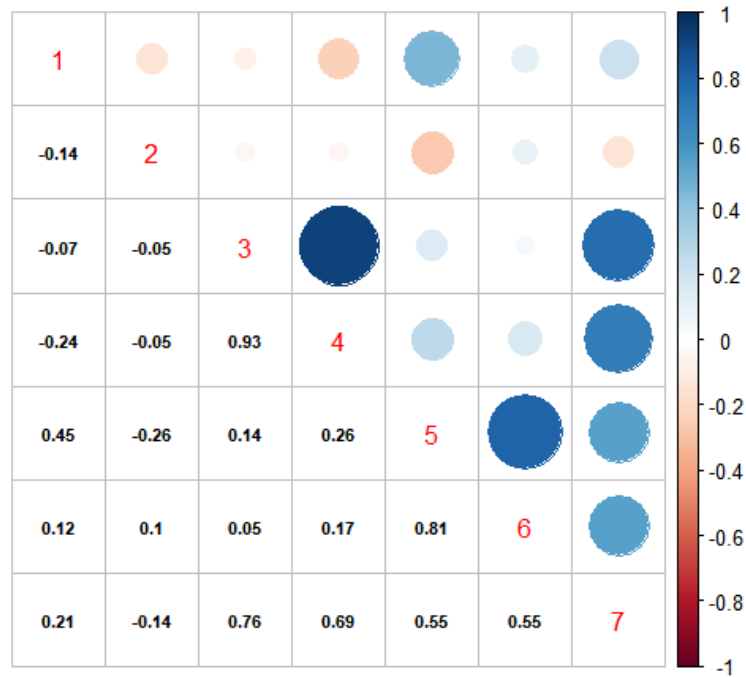


Figure C.5: Round Two, Question 7 Correlation Plot

A correlation plot that compares the round two, question 8 rankings is shown below in Figure C.6. The average agreement correlation was 0.23, which indicated a fairly weak agreement. The strongest agreement correlation was 0.89, between participants three and five, which indicated a strong agreement. The lowest agreement correlation was -0.37, between participants one and seven, which indicated a fairly weak disagreement.

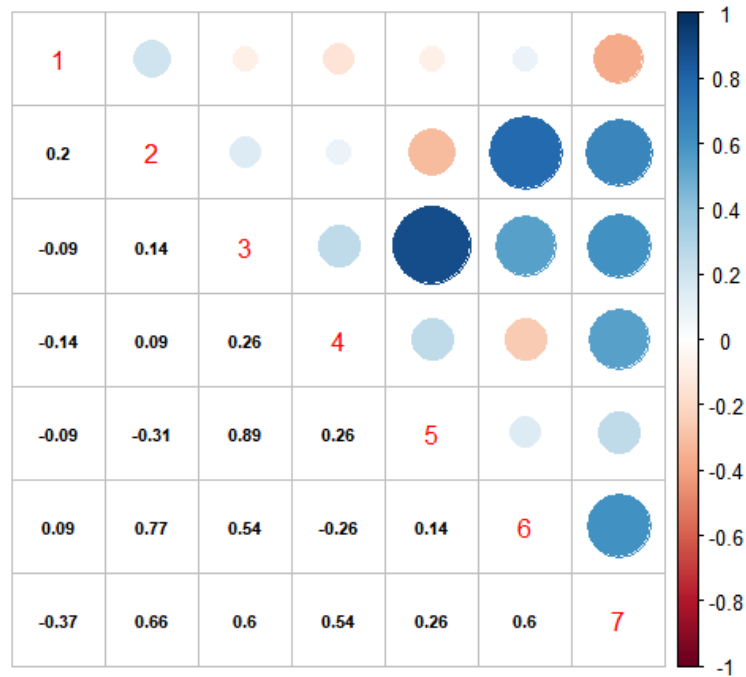


Figure C.6: Round Two, Question 8 Correlation Plot

A correlation plot that compares the round two, question 9 rankings is shown below in Figure C.7. The average agreement correlation was 0.60, which indicated a fairly strong agreement. The strongest agreement correlation was 0.90, between participants one and two, which indicated a very strong agreement. The lowest agreement correlation was -0.05, between participants four and five, which indicated that their opinions are fairly unrelated.

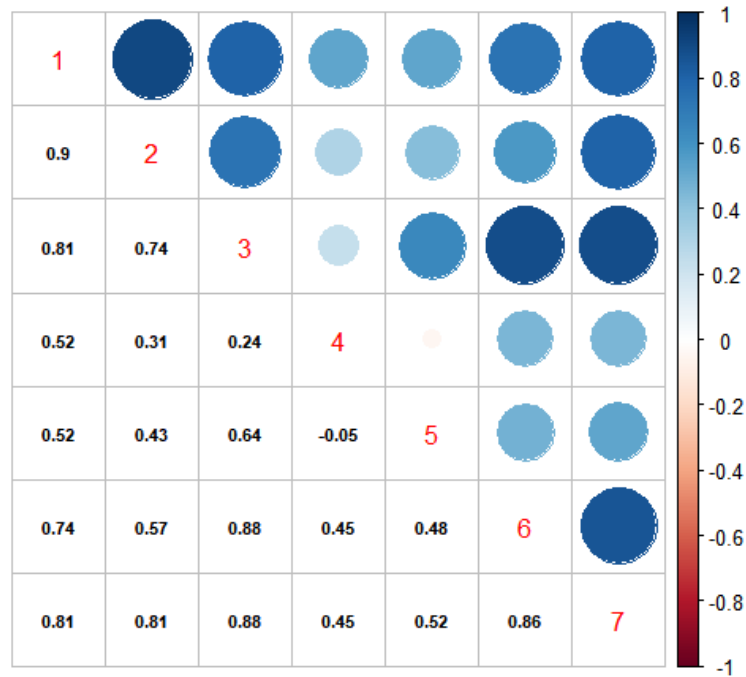


Figure C.7: Round Two, Question 9 Correlation Plot

A correlation plot that compares the round two, question 10 rankings is shown below in Figure C.8. The average agreement correlation was 0.18, which indicated almost no agreement. This average was skewed by strong agreements and strong disagreements between respondents. The strongest agreement correlation was 0.81, between participants three and six, which indicated a strong agreement. The lowest agreement correlation was -0.76, between participants five and seven, which indicated a strong disagreement.

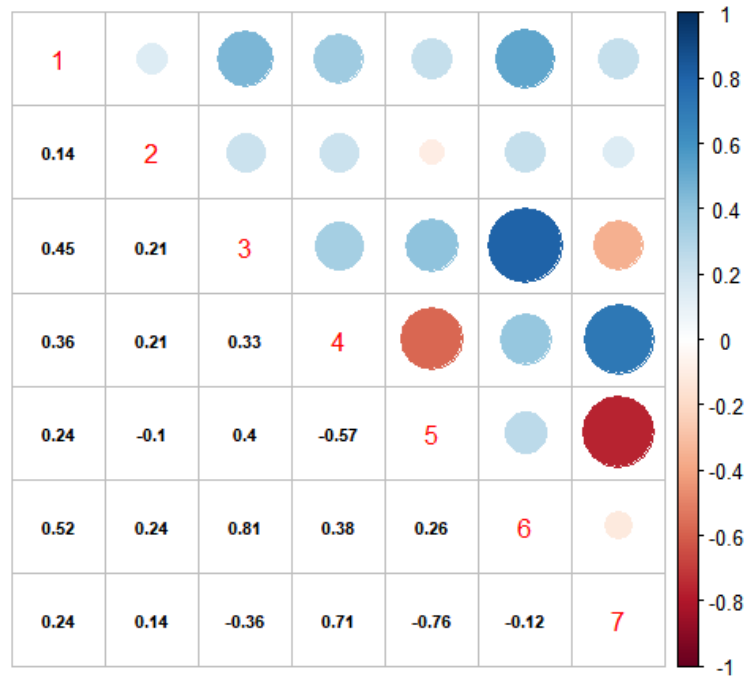


Figure C.8: Round Two, Question 10 Correlation Plot

A correlation plot that compares the round two, question 11 rankings is shown below in Figure C.9. The average agreement correlation was 0.43, which indicated a fairly weak agreement. The strongest agreement correlation was 0.96, between participants two, three, and four which indicated a near perfect agreement. The lowest agreement correlation was -0.43, between participants five and seven, which indicated a weak disagreement.

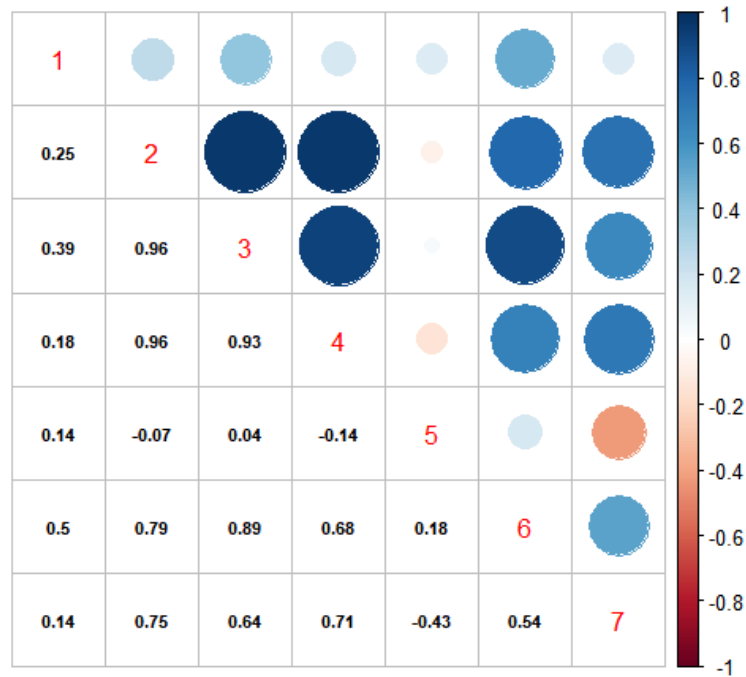


Figure C.9: Round Two, Question 11 Correlation Plot

A correlation plot that compares the round two, question 12 rankings is shown below in Figure C.10. The average agreement correlation was 0.16, which indicated almost no agreement or disagreement. This average was skewed by strong agreements and strong disagreements between respondents. The strongest agreement correlation was 0.81, between participants one and seven, which indicated a strong agreement. The lowest agreement correlation was -0.79, between participants two, three, and five, which indicated a strong disagreement.

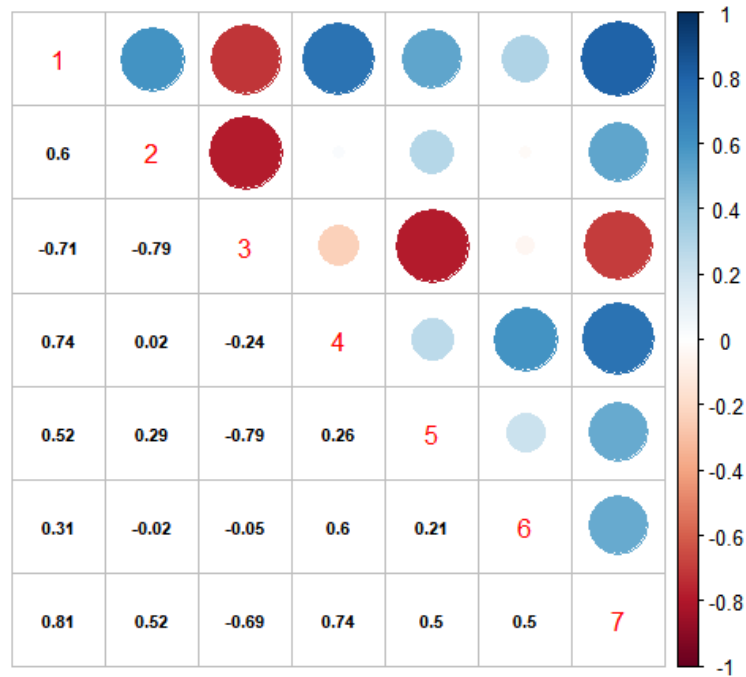


Figure C.10: Round Two, Question 12 Correlation Plot

C.2 Round 3 Pair-Wise Correlation

Correlation plots were also developed as an analytical tool for round three. These plots, are generated in RConsole, and compare each participant's rankings with each other participant. A positive correlation will indicate agreement between individuals. A correlation close to zero will indicate that participants opinions are unrelated to one another, and a negative correlation will indicate that individuals' priorities are opposed. Each correlation plot included in this research effort provides both a numerical correlation (below and left) and a graphical correlation (above and right).

A correlation plot that compares all of the round three agreements is shown below in Figure C.11. The average agreement correlation is 0.09, which indicates that respondents

opinions of the aggregated rankings are independent and unrelated to each other. The strongest agreement correlation is 0.63, between participants five and seven, which indicates a fairly strong agreement. The lowest agreement correlation is -0.50, between participants two and six, which indicates a fairly strong disagreement.

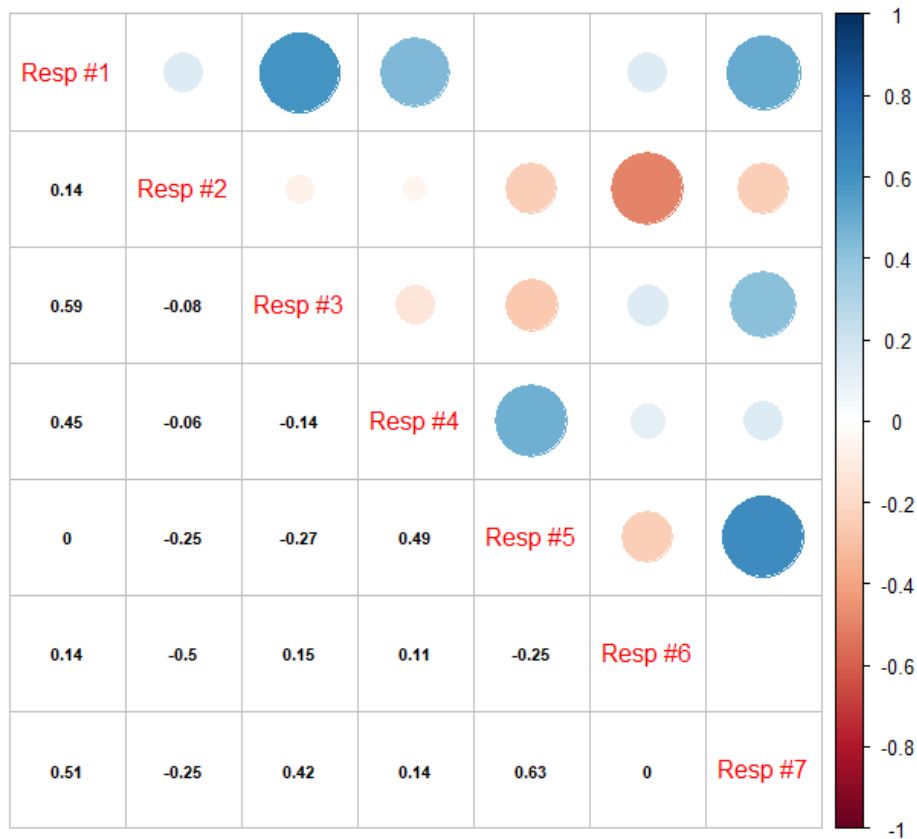


Figure C.11: Round Three Correlation Plot

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14. ABSTRACT Asset Management has a history of policy mandates within the US Government dating back to 1990's. In order to accomplish these many directives, the Air Force Civil Engineer community has adopted a mindset and framework commonly referred to as Asset Management. Despite numerous references and guidance to establish Asset Management principles, the Air Force has not yet developed a clear and concise way to define or measure overarching success in Asset Management. This research effort focuses on closing the knowledge gap between issued policy and implementation. It examines Asset Management implementation efforts in other government agencies, private industries, and in various countries around the world. Combining this information with interviews from Subject Matter Experts at various levels of the Air Force Civil Engineering structure, this research identifies: current implementation limitations, key elements that constitute and promote success, barriers to success, military-unique opportunities for success, internal success identifiers, ways to promote continuous improvement, and the essential behaviors within Air Force Asset Management. Using this information and recommendations from the Air Force SMEs, suggestions are presented for measuring and incentivizing Asset Management success within an organization. Some of the major findings of this study were the need to develop both a clear definition of what asset management is and an official SAMP for the Air Force. Other findings of this research effort included: the importance of leadership buy-in; complete and accurate facility inventory; and understanding of asset management principles at all levels of the organization.						
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