12-2022

Project Selection in Facility and Infrastructure Maintenance Organizations

Bayram M. Kurbanov

PROJECT SELECTION IN FACILITY AND INFRASTRUCTURE MAINTENANCE ORGANIZATIONS

THESIS

Bayram Kurbanov

AFIT-ENV-MS-22-D-033

DEPARTMENT OF THE AIR FORCE AIR UNIVERSITY

AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

AFIT-ENV-MS-22-D-033

PROJECT SELECTION IN FACILITY AND INFRASTRUCTURE MAINTENANCE ORGANIZATIONS

THESIS

Presented to the Faculty

Department of Systems Engineering and Management

Graduate School of Engineering and Management

Air Force Institute of Technology

Air University

Air Education and Training Command

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Engineering Management

Bayram M. Kurbanov, B.S.

December 2022

AFIT-ENV-MS-22-D-033

PROJECT SELECTION IN FACILITY AND

INFRASTRUCTURE MAINTENANCE ORGANIZATIONS

Bayram M Kurbanov, B.S.

Committee Membership:

Alfred E. Thal, Jr., PhD
Chair

Christopher M. Chini, PhD
Member

Brigham A. Moore, Maj, USAF, PhD
Member

Abstract

The current Air Force Civil Engineer Center (AFCEC) built infrastructure Facility Sustainment Restoration and Modernization (FSRM) portfolio management methodology results in an unbalanced project portfolio. The consequence of this unbalance is that majority of the funding goes towards buildings on the flightline and Facility Support Services activities do not get adequate funding which leads to further deterioration of those facilities. This research investigates whether decision support framework based on Value-Focused Thinking (VFT) process yields better project selection outcomes for facility and infrastructure maintenance organizations. To accomplish that, the investigation focuses on understanding current AFCEC decision support methodology, building an alternative one based on VFT process, and then applying the result to a sampling of projects. Findings of the investigation prove that the VFT process yields a decision support framework that successfully balances FSRM project portfolio by ranking the projects based on their level of contribution to decision-maker's values affecting facility and infrastructure maintenance organizations.

Table of Contents

Page

List of Figures

Page

List of Tables

Page

PROJECT SELECTION IN FACILITY AND

INFRASTRUCTURE MAINTENANCE ORGANIZATIONS

Chapter I. Introduction

Traditionally, decision-makers made project funding decision by assessing a range of proposals that were presented to them. This approach limited creativity by constraining decision making to a set number of options. However, there is a better methodology out there, the one that encourages creativity and, as a result, leads to better outcomes for organizations. This methodology is called Value-Focused Thinking (VFT). By providing examples, this chapter shows that VFT is a time-proven methodology that has successfully been used by global industry and governments. The chapter explains challenges with the current Air Force Civil Engineer Center (AFCEC) required project selection methodology and suggests using VFT to overcome those challenges. Finally, this chapter describes how recent changes that the Air Force made to the business rules governing project selection encourages local use of VFT based project selection.

1.1. Background

Using decision analysis with Value-Focused Thinking (VFT) as a methodology to select projects for execution has been gaining popularity. The traditional way of choosing projects for execution has been based on picking projects from a list of suggested proposals. These proposals would be submitted by stakeholders of an organization and then a decision-making entity would compare the merits of the proposals against each other to decide which proposals the decision-maker would fund. This approach to decision-making is called Alternative Focused Thinking (AFT). However, the AFT is seriously handicapped when it comes to aligning projects that the organization takes on with the strategic goals of the decision-maker. The AFT approach is incapable of quantifying how much a project contributes towards achieving strategic goals of a decision-maker. Therefore, an alternative to Alternative Focused Thinking is VFT, which is a versatile methodology that has been used globally across various industries and in a variety of disparate fields. For example, VFT was used to identify the values of Massive Open Online Courses (MOOCs) in education from students' perspectives in China (Gao et al., 2018). VFT was used to select a portfolio of distributed energy generation projects in the Brazilian electricity sector (Bortoluzzi et al., 2021). VFT facilitated understanding of how to maximize end-user security and privacy concerns in Social Networking Services (Barrett-Maitland et al., 2016).

VFT in decision-making has been used extensively in the United States as well. For example, the Electric Power Research Institute (EPRI) sponsored a project to develop a methodology for involving stakeholders concerned about Los Angeles's air pollution (Keeney, 1992). VFT was used to accomplish the goal. VFT is uniquely suitable for this type of problem since air pollution is an issue that affects everyone. It is an ideal tool to provide a common understanding of the problem by developing a value structure agreeable to all the stakeholders. Another study that was funded by EPRI of Palo Alto, California, dealt with determining the objectives of a comprehensive research problem to address climate change issues (Keeney, 1992). Decisions involved in combating climate change and mitigating its consequences are among the most important humanity has ever faced. The use of VFT to develop a decision framework for such a task speaks highly of the trust decision-makers have in this methodology. The Department of Energy (DOE) used VFT to successfully analyze alternatives for the disposition of surplus weapons-grade plutonium (Dyer, 1999). DOE also used VFT to evaluate metal cask systems used for shipping spent nuclear fuel from nuclear power plants to storage locations (Westinghouse, 1986).

The Air Force has a history of utilizing VFT for decision-making. The VFT methodology was used to devise a value model called Foundations 2025. This decision support model was used by the Air Force to decide which capabilities the United States will require to possess the dominant air and space force in the future (Fogleman, 1994). The model achieved the goal by examining numerous and varied emerging technologies, platforms, and weapons systems (Air University, 1996). Additionally, the VFT methodology was used by Air Force Research Laboratories Air Vehicles Directorate (Winthrop, 1999) and the National Air Intelligence Center (Cox, 1997) to decide how to allocate their limited resources to accomplish missions set out for them by the Department of Defense. It was also used by the Force Protection Battlelab (FPB) to select force protection initiatives for evaluation (Jurk, 2002).

VFT has been applied to a variety of fields globally in both the private sector and the federal government. However, an exhaustive search of peer-reviewed publications has not revealed any instances where the VFT has been applied to the selection of Facility Sustainment Restoration and Modernization (FSRM) projects for execution. A lot of Air Force infrastructure is outdated, beyond its useful life, and in severe need of being replaced. FSRM funding, on the other hand, has been sparse and uneven throughout recent decades. In such an environment, it is extremely important to select projects that align funding to keep the mission going. VFT is an ideal tool to accomplish this goal because it is a value-driven decision-making process.

Edwards AFB Civil Engineering Group leadership was asked about a suitable thesis topic that would benefit the base. The group leadership agreed that there is a need to investigate how

AFCEC could change the way it makes FSRM project funding decisions. The leadership complained that they could not get significant funding to renovate buildings occupied by Facility Support Services activities, like the Officer's Club, Security Forces, etc. They stated that AFCEC needed a better methodology to manage its project portfolio that would provide more uniform distribution of funding across the base assets. The view was that assets on the flightline get all the funding while all other buildings get neglected.

The current process AFCEC uses to prioritize FSRM projects in a 5-year outlook across the Air Force is called the Air Force Comprehensive Asset Management Plan (AFCAMP). Beginning with the fiscal year 2020 AFCAMP, AFCEC made a change to how it funded FSRM projects. On 23 May 2018, the Office of the Air Force Deputy Chief of Staff for Logistics, Engineering, and Force Protection issued an Air Force Guidance Memorandum to AFI 32-1032, Planning and Programming Appropriated Fund Maintenance, Repair, and Construction Projects (see Appendix A). The memorandum states:

> *3.2.1. In order to support the Chief of Staff of the Air Force's efforts to reinvigorate squadrons and develop leaders as well as decrease the effort required by civil engineers at every organizational level, wing's will assume greater responsibility to fund relatively small dollar repair projects beginning with the Fiscal Year 2020 AFCAMP. Installations competing for centralized facility repair project funding via the AFCAMP will not submit projects less than the following thresholds to enable and allow for localized prioritization:*
>
> > *Sustainment repair projects - $2 million*
> >
> > *Restoration & Modernization repair projects - $1 million*

Although the stated reason for this change is to reinvigorate squadrons and develop leaders as well as reduce the effort required by civil engineers, a beneficial side effect of this change is that bases will be able to fund local projects that base leadership deems important. However, base leadership still requires a transparent, repeatable, and defendable decision support mechanism which needs to be based on a tested and successfully applied methodology. This research aims to define an alternative decision support methodology for FSRM projects and use it to develop a decision support mechanism that will result in a balanced portfolio of FSRM projects.

1.2. Research Problem

According to the 412th Civil Engineer Group (CEG) leadership, the current AFCEC-built infrastructure FSRM decision support framework results in an unbalanced project portfolio. Therefore, it is an inadequate tool for project selection. The consequence of an unbalanced project portfolio is that the majority of the funding goes towards buildings on the flightline, and mission Support Services activities do not get adequate funding, which leads to further deterioration of those facilities. The installation commander, as the decision-maker, requires a decision support mechanism that would support the selection of projects which are in line with his or her values. It is the purpose of this research to utilize the VFT methodology to devise a decision support mechanism based on Edwards AFB commander's values which, when applied to the selection of FSRM projects, is expected to result in a balanced project portfolio. A balanced portfolio of projects is defined as one that does not rank order projects based exclusively on a single factor, but gives appropriate priority to all the factors which are of concern for the decision maker. In other words, a balanced portfolio consists of projects ranked according to their level of contribution to fulfilling all the values of the decision maker.

1.3. Research Questions

Covering 482 square miles, Edwards AFB is the second-largest base in the United States. The base is located in Southern California and hosts the 412th Test Wing (TW), which is responsible for planning, conducting, and analyzing test missions and reports on flight and ground testing of aircraft, weapons systems, software, components, modeling, and simulation for the Air Force. The 412th Civil Engineer Group (CEG), one of 11 groups that make up the 412th TW, is responsible for building, maintaining, and repairing real property on base. It is also responsible for planning and executing emergency management operations, fire service support to the base, Explosive Ordnance Disposal (EOD) operational support to base ranges, and environmental stewardship of the base. The base infrastructure that CEG is responsible for is vast. It consists of 216 miles of paved roads, 7.8 miles of paved runways, 13.8 million square feet of airfield ramp space, 8.2 million square feet of building space, 130 miles of natural gas lines, and 270 miles of electrical lines. This vast amount of natural and built resources needs to be maintained and repaired. However, the current decision support framework utilized by the base does not allow for a balanced distribution of the funding. Instead, it channels most of the funding into flightline facilities. Although flightline facilities are indeed important, the base also values and requires infrastructure that is not necessarily physically on the flightline. Therefore, the base requires a decision support framework based on a methodology that is proven to yield results in line with decision-maker's values.

The overarching research question this thesis set out to answer is: How can a decision support framework be created that ranks FSRM projects for funding in facility and infrastructure maintenance organizations and results in a balanced portfolio of projects? The three investigative questions listed in the following paragraph guided the research.

The first investigative question the research set out to answer is concerned with understanding the history behind the current decision support mechanism utilized by AFCEC. The first question is: Why does the current AFCEC decision support framework score facilities occupied by base Facility Support Services lower than facilities located on the flight line? By understanding the mechanics and shortcomings of the currently utilized framework, the research strives to avoid repeating the errors that resulted in a requirement to build an alternative decision mechanism. The second investigative question deals with understanding the VFT methodology and how it can be applied to the construction of a new, value-based decision support framework. The second question is: What would the resultant decision support framework be for FSRM projects if the Value Focused Thinking methodology was adopted by Edwards AFB? Understanding the methodology will enable the creation of a roadmap for decision-makers to follow to develop a VFT-based decision support framework for FSRM projects. The third investigative question this research set out to answer focuses on the application of the newly developed VFT-based decision support framework to the evaluation of several FSRM projects. The third question is: Which projects should 412 CEG pursue to fulfill its mission? Application of the framework to a sampling of projects will enable an analysis of the results and comparison between the VFT-based decision support framework and the legacy one.

1.4. Methodology

The Value Focused Thinking methodology is selected for developing the Edwards AFB decision support framework. "Values are more fundamental to a decision problem than are alternatives" (Keeney, 1992, p.3). The goal of any decision is to produce outcomes desirable to the decision-maker and to avoid undesirable ones. The desirable outcomes are those in line with decision-maker's values. Therefore, decision alternatives are merely means of achieving those desired values. The VFT methodology systematizes the definition and articulation of values to create or select alternatives and evaluate their desirability for a decision-maker. "Value-focused thinking essentially consists of two activities: first deciding what you want and then figuring out how to get it" (Keeney, 1992, p.4).

In case the of the 412th CEG, alternatives are projects competing for FSRM funding. These alternatives have various origins. Projects can be generated externally by a request from any of the organizations on base, they can be created internally within CEG by one of the Sustainment Management Systems used by CEG Operations Engineering, or they could be generated by one of the base real property condition surveys such as Pavement Condition Evaluation Survey.

Values will be determined by a panel consisting of 412th Civil Engineering Group project programmers and leadership. These values will be used to develop a decision support framework by means of utilizing the VFT methodology. The framework will aim to balance the Air Force and base-level perspectives on project selection. The 412th Civil Engineer Group project programmers and leadership possess necessary local and Air Force-wide knowledge and experience for this research. Therefore, they are best positioned to be members of this panel. The resultant value framework will be used to evaluate project alternatives for FSRM funding.

1.5. Assumptions and Limitations

The installation commander for Edwards AFB is the ultimate decision-maker when it comes to selecting real property projects for any sort of funding. However, it would be impossible for the installation commander to review hundreds of individual projects lined up for maintenance, repair, and construction. Therefore, the installation commander delegates this responsibility down to Base Civil Engineer (BCE) who, in turn, relies on his or her staff to review, evaluate, and rank order projects on the installation commander's behalf. Therefore, an assumption has to be made that a panel consisting of 412th Civil Engineering Group project programmers and leadership knows the installation commander's mind and therefore is suited to devise an appropriate decision support framework. Ideally, the installation commander should be the person who determines the values for the framework. However, it would be impossible for the installation commander to find enough time to sit through the extensive discussions needed for this research.

1.6. Review of Chapters

Chapter II consists of a literature review. It discusses the current Air Force decision support framework and the challenges associated with the framework. It also discusses Value Focused Thinking and the steps an decision-maker needs to go through to implement VFT in order to develop a decision support framework. Chapter III discusses how the VFT methodology is implemented to develop a decision support framework for use by the 412th CEG on FRSM projects that qualify for base-level funding. Chapter IV performs deterministic and sensitivity analyses of the results. Finally, Chapter V discusses the findings of the study, the strengths and weaknesses of the developed value model, and the model's likely impact on local-level project selection. It also includes recommendations for future work.

Chapter II. Literature Review

This chapter details research that has been conducted in the past concerning Air Force asset management and VFT. The Air Force Asset Management section describes the extent and variety of the Air Force assets and the need for their deliberate management. The section defines asset management and introduces the history of asset management in the U.S. Air Force. It describes asset management principles and processes that systematize the administration of the built and natural assets. The section ties management of project portfolios to assest management. Finally, this section introduces the Air Force Comprehensive Asset Management Plan (AFCAMP) Integrated Priority List (IPL) process. AFCAMP IPL process is current Air Force decision support framework for Facility Sustainment Restoration and Modernization (FSRM) project funding. The second section describes AFCAMP IPL project scoring rules. It accomplished the task by explaining the origins and mechanics behind calculating AFCAMP concepts of Mission Dependency Index (MDI) and Functional Condition Index (FCI). The section on the Air Force portfolio selection procedure challenges describes multiple significant problems that arise as a result of the Air Force adopting MDI as a factor in decision making. Final sections of this chapter define Value Focused methodology and review a 10-step process for building a VFT-based decision support framework.

2.1. Air Force Asset Management

The United States Air Force is required to provide the government with capabilities to enable global reach, global vigilance, and global power. According to the Air Force 2023 Implementation Plan (United States Air Force, 2013), each of these major capabilities requires the Air Force to be proficient in the 20 subfields listed in Table 1.

Table 1. Air Force Major Capabilities and Respective Subfields (United States Air Force, 2013)

Major Capability	Subfield
Global Vigilance	Space Superiority (Global Space Mission Operations)
	Strategic Warning
	Space Situational Awareness
	Global ISR (includes all domains)
	Defensive Cyberspace Operations
	Theater Missile Warning
	Theater ISR (Airborne and Cyberspace)
Global Reach	Air Refueling (to enable global operations)
	Inter-theater Airlift
	Theater Air Refueling
	Intra-theater Airlift
	Aeromedical Evacuation
Global Power	Nuclear Deterrence Operations
	Global Command and Control (C2)
	Global Precision Attack (includes Offensive Cyberspace Ops)
	Space Superiority (Space Control)
	Theater C2
	Theater Air Superiority
	Theater Precision Attack (Interdiction, Special Ops, Close-Air-Support, Offensive Cyberspace Ops
	Combat Search and Rescue (Personnel Recovery)

To perform its complex mission, the Air Force needs to maintain a huge number of physical assets across the entire world. The Department of Defense (DoD) Base Structure Report (2013) indicates that the Plant Replacement Value (PRV) of all the Air Force worldwide real property assets is an estimated $259 billion. These assets are diverse in their type, condition, and functions as they were acquired at various times for varying purposes. All of these built and natural assets need to be maintained and repaired. However, the money to perform maintenance and repair is limited by Air Force budget constraints. As the assets are so diverse, it is very difficult to determine which asset-related projects must be funded and which could be delayed. Therefore, there is an obvious need for an asset management system that would systematize asset-related data collection, processing, and selection for funding across the Air Force. The decision support framework used to select assets for repair and maintenance funding is part of the overarching asset management system. Therefore, to understand the decision support framework that the Air Force uses to select projects for funding, we need to understand the principles of Air Force asset management.

"“Asset Management” is a systematic process of maintaining, upgrading, and operating physical assets cost-effectively" (McElroy, 1999, p.1). The field of asset management is concerned about physical assets, also called real property assets. Asset management combines principles of economics, business, and engineering to most effectively leverage and preserve built and natural assets (McElroy, 1999). The field is vast and complex as it tries to manage a great variety of built and natural assets. Motivations for asset management practices include the effective use of resources, gaining a competitive advantage, increasing profit margin, and ensuring accountability (Smith, 2016). Asset management is performed in both private and public domains. It is important in the public domain because of "public demands for transparency in government decision-making, greater accountability for those decisions, and greater return-on-investment" (McElroy, 1999, p.1).

Federal agencies, including the Air Force, started implementing asset management principles in 2004 when Executive Order (EO) 13327 directed them to adopt those principles in handling their respective real property assets. Federal real property is "any real property owned, leased, or otherwise managed by the federal government, both within and outside the United States, and improvements on Federal lands" (Executive Order No. 13327, 2004). Executive Order 13327 establishes the Federal Real Property Council (FRPC) under the Office of Management and Budget (OMB) which is responsible for developing guidance and facilitating the success of the federal agency's asset management plans. The FRPC subsequently developed the guiding asset management principles outlined in Table 2. Asset management principles standardize how data characterizing various assets is collected, organized, processed, and presented to decision-makers so that decision-makers can make informed and effective decisions. The FRPC standardized the categories shown in Table 3 for federal real property data to be collected and produced.

Table 2. FRPC Developed Guiding Asset Management Principles (Teicholz et al., 2005)

Ten guiding asset management principles
1. Support agency mission and strategic goals
2. Use public and commercial benchmarks and best practices
3. Employ life-cycle cost-benefit analysis
4. Promote full and appropriate utilization
5. Dispose of unneeded assets
6. Provide appropriate levels of investment
7. Accurately inventory and describe all assets
8. Employ balanced performance measures
9. Advance customer satisfaction
10. Provide safe, secure, and healthy workplaces

Table 3. FRPC Standardized Federal Real Property Data Categories (Teicholz et al., 2005)

Primary Data Elements	**Performance Measures**
Asset ID	Utilization
Location/Address	Condition Index
Real Property Type	Mission Dependency
Real Property Use	Annual Operating Costs
Legal Interest	
Status	
Historical Status	
Using Organization	
Size	
Value	

Real property assets are separated into two major categories: built and natural infrastructure. Natural infrastructure is land, air, and natural water resources relating to the installation (United States Air Force, 2014). Built infrastructure are assets that are constructed using manpower and machines. Built infrastructure is divided into these categories: facilities, energy assurance infrastructure, transportation and pavements, and utilities (AFCEC, 2019). Although all of these assets are part of built infrastructure, the physical characteristics of these assets are very different from each other. Due to these differences, the type of data collected and the methods used to generate the data describing the condition of each type of asset are also different. Information regarding the condition of existing built and natural infrastructure assets is used to generate Facility Sustainment Restoration and Modernization (FSRM) projects. Once the projects are created, there is a need to prioritize them to determine which projects should be funded. This is the stage where a decision support framework is needed to manage the portfolio of project proposals.

"A project portfolio is a group of projects and programs aimed at strategic objectives that share resources and compete for funding. Each portfolio supports a theme ... Any program or project that contributes to or falls within a particular theme is added to the portfolio" (Nicholas & Steyn, 2017, p. 604). The Air Force manages many different project portfolios. Some examples are Military Construction (MILCON), Military Family Housing (MFH), Operations & Maintenance (O&M), and Non-Appropriated Funds (NAF) project portfolios. Built infrastructure FSRM projects are a subset of the O&M project portfolio. These are projects related to the built infrastructure that require maintenance, repair, or modernization.

Air Force Programming Plan (P-Plan) for Implementation of Enterprise-Wide Civil Engineer Transformation (2014) introduces the Air Force Comprehensive Asset Management

Plan (AFCAMP) Integrated Priority List (IPL) process. According to the P-Plan, base-level civil engineering organizations in the Air Force get the majority of their funding for FSRM projects through the Air Force Comprehensive Asset Management Plan (AFCAMP) Integrated Priority List (IPL) process. The P-Plan states that Civil Engineering breaks out FSRM projects into four activities: Real Estate & Natural Infrastructure, Airfield and Transportation Networks, Utilities, and Facilities. Every base puts together an Activity Management Plan (AMP) for each of these four areas. The AMP is a product of the Air Force asset management process. It is devised to manage a lengthy list of unfunded FSRM requirements. Each AMP contains historical information concerning respective activities and assessments of the condition of the various assets that make up each of the four activities. This enables the base to "rack and stack" the list of projects and determine when they need to be executed before the infrastructure in question fails. The four base AMPs then feed into a combined list of requirements known as the Base Comprehensive Asset Management Plan (BCAMP). The BCAMP in-turn is "racked and stacked" by the Base Facility Board which produces an IPL to represent a list of competing requirements outlined in the AMPs, and each project is scored based on a scoring process developed by AFCEC. Each base BCAMP is sent to AFCEC for integration into the AFCAMP IPL. AFCEC then racks and stacks the AFCAMP IPL in what is called a governance process. During this process, the technical merits of each project are evaluated by AFCEC subject matter experts, and each MAJCOM racks and stacks its base projects based on the importance of the project to the MAJCOM's mission. Finally, the P-Plan explains that AFCEC establishes a project funding line based on estimated available project funding for the next fiscal year. Projects above the funding line are listed in the fiscal year construction tasking order (CTO) and authority to advertise these projects is given. The projects below the funding line will need to be re-competed the following year.

The AFCEC FY21-25 AFCAMP Business Rules (2019) publication describes the process used to prioritize projects on the IPL using technical scores, which are acquired by assessing the Probability of Asset Failure and the Consequence of Asset Failure of a given real property asset. However, if the project generates cost savings as either an energy project or Third Party Finance project, they do not compete for funding and no technical score is developed. The AFCAMP Business Rules publication explains that the Probability of Failure and Consequence of Failure are both assessed on a scale from 1 to 100. A technical score for a project is acquired by multiplying its score for the Probability of Asset Failure by its score for the Consequence of Asset Failure. Therefore, the maximum technical score that any project can achieve is 10,000. The Consequence of Failure score is a combination of Mission Dependency Index (MDI) and MAJCOM Mission Impact scores. According to Nichols (2015), the MDI score for each facility type is predetermined by AFCEC. Facilities that have high MDIs are those whose failure would directly jeopardize the performance of the Air Force mission. Therefore, facilities like airfields and hangars are assigned the highest MDIs. Nichols (2015) explains that facilities with high MDIs compete well at the AFCAMP level because the MDI is a much bigger proportion of the total Consequence of Failure score than the MAJCOM Mission Impact score. Facilities occupied by base support personnel get assigned much lower MDI scores and, therefore, compete poorly at the AFCAMP level. In fact, the current MDI score distribution makes it practically impossible for facilities occupied by base Facility Support Services activities, like the Officer’s Club, child care, etc., to get any funding through the IPL process. The next section describes in detail how the Air Force scores projects for the IPL process.

2.2. Current Air Force Decision Support Framework for FSRM Project Funding

The current Air Force decision support framework for ranking FSRM projects for funding employs the performance measures of Mission Dependency in conjunction with Condition Index to determine the best combination of projects to fund in each fiscal year. The Functional Condition Index (FCI) gives a numerical value to the condition of a facility (AFCEC, 2019). In order to understand how the FCI is derived for a built asset, we need to understand its lifecycle. Uddin, Hudson & Haas (2013) explain the lifecycle stages of a built asset. Any built asset's lifecycle consists of planning/design, construction, operation and maintenance, and demolition phases. The planning/design phase is a phase where an asset goes from a concept in the owner's mind to a set of drawings and specifications. The construction phase is where an asset is built in accordance with drawings and specifications. The operation and maintenance phase is where an asset is actually used by the owner to perform its intended purpose. Finally, the demolition phase is when the asset is at the end of its life and it is removed from the infrastructure inventory.

The operation and maintenance phase is the longest and the most expensive of all the phases (Grussing, Uzarski, & Marrano, 2006). The cost of this phase ultimately exceeds the cost of the construction phase. Therefore, targeting this phase for cost reduction can ultimately result in significant cost savings for the asset owner. However, these cost savings can only be realized through careful planning and timing of the maintenance work. Deferred maintenance and repair of an asset leads to accelerated deterioration and an increase in restoration costs for it. The best practice approach to facility management can lower total maintenance and repair costs by nearly half over a 50-year lifecycle (Grussing et al., 2006).

Air Force Civil Engineer Sustainment Management Systems Playbook (2022) explains that to find this “sweet spot” for building repair, we first need to assess the condition of an asset. The playbook explains that every asset is made up of components. These components are major systems for an asset. For example, the major components of a building are its electrical system, plumbing system, HVAC system, sewer system, structural frame and foundation, roof, etc. The functional condition assessment of an asset is performed through physical inspection of asset components and by analyzing historical repair data pertaining to the asset. This data is used to derive the FCI, which is an asset component condition assessment method and metric that objectively represents the building component condition on a scale from 0 to 100. The index is calibrated so that total component deterioration corresponds to an FCI of 40 and a brand new building has an FCI of 100 for all its components. A composite FCI can be put together for an asset using the FCIs of its components. Repairing an asset increases the FCI, which decreases over time as the building deteriorates. Experience has shown that for a wide variety of asset components, the repair “sweet spot” falls in an FCI range of 75-85 (AFCEC, 2022). Performing repairs at the sweet spot can result in significant cost avoidance by preventing critical failures late in the lifecycle of an asset. Therefore, the lifecycle cost of facility ownership is decreased by accurately timing necessary repairs and replacement of components over the lifespan of an asset (Grussing et al., 2006).

The FCI is used in portfolio management to compare the conditions of all assets that make up the Air Force infrastructure. However, FCI comparison is not sufficient for planning purposes because it does not take into account the benefit of the asset. In other words, it does not account for the value of an asset to the installation commander and the associated risk of not having the facility available to the installation commander. The value of an asset to the decision-maker is determined by how well this asset supports the mission of that decision-maker. The most common way to value an asset is to use its Mission Dependency Index (MDI). The MDI approach was first defined in the year 2000 at the Naval Facilities Engineering Service Center in conjuction with the U.S. Coast Guard's Office of Civil Engineering. The MDI is a means of putting a number on the criticality of a facility. This number helps compare an asset to other assets in the portfolio and accordingly rank it in line for budget funds for repairs. The MDI is based on an algebraic formula developed by Kujawski and Miller (2009).

$$MDI = 26.54 * \left[MD_w + 0.125 * \frac{1}{n}\sum_{i=1}^{n} MD_{bi} + 0.1 * \ln(n)\right] - 25.54 \qquad (1)$$

Mission intra-dependency (MD_w) strives to capture the dependencies within a given functional area, while mission inter-dependency (MD_b) strives to capture dependencies between functional areas. The *n*-component in the equation represents the actual number of mission interdependencies. The U.S. Navy determines values for both variables by conducting the four-question survey of mission and facility stakeholders shown in Table 4. Possible responses and definitions of those responses are shown in Tables 5 and 6.

Table 4. Navy MDI Survey Questions (Antelman, 2008)

Primary Topic	Measure	Metric	Question #	Question Verbiage
Intradependency	Interruptibility	Duration (Time)	1	How long could the "functions" supported by the (facility, structure, or utility) be stopped without adverse impact on the mission?
	Relocateability	Difficulty	2	If your (facility, structure, or utility) was not functional, could you continue performing your mission by using another (facility, structure, or utility), or by setting up temporary facilities?
Interdependency	Interruptibility	Duration (Time)	3	How long could the services provided by (named functional area) be interrupted before impacting your mission readiness?
	Replaceability	Difficulty	4	How difficult would it be to replace or replicate the services provided by (named functional area) with another provider from any source?

Table 5. Response Options for Interruptability (Antelman, 2008)

Interruptibility Responses (Time)	
Response	**Definition**
None (N)	The functions performed within the facility must be maintained continuously (24/7)
Urgent (U)	Minutes not to exceed 30 minutes
Brief (B)	Minutes or hours not to exceed 24 hours
Short (S)	Days not to exceed 7 days
Prolonged (P)	More than a week

Table 6. Response Options for Relocateability and Replaceability (Antelman, 2008)

Relocateability and Replaceability Responses (Difficulty)	
Response	**Definition**
Impossible (I)	There are no known redundancies or excess/surge capacities available, or there are no viable commercial alternatives – only this site/command can provide these services
Extremely Difficult (X)	There are minimally acceptable redundancies or excess/surge capacities available, or there are viable commercial alternatives, but no readily available contract mechanism in place to replace the services
Difficult (D)	Services exist and are available, but the form of delivery is ill-defined or will require a measurable and unbudgeted level of effort to obtain (money/man-hours), but mission readiness capabilities would not be compromised in the process
Possible (P)	Services exist, are available, and are well defined

Responses to questions in Table 4 are used in two matrices similar to the probability-severity matrix from the classical operational risk management (ORM) method. Each matrix produces a number which is then input into Equation (1) to calculate an asset's MDI score (Kujawski & Miller, 2009). These matrices are shown in Figures 1 and 2.

MISSION INTRA-DEPENDENCY SCORE					
MD_W		Q1: Interruptability			
		Immediate (24/7)	Brief (min/hrs)	Short (<7days)	Prolonged (>7days)
Q2: Relocateability	Impossible	4.0	3.6	3.2	2.8
	Extremely Difficult	3.4	3.0	2.6	2.2
	Difficult	2.8	2.4	2.0	1.6
	Possible	2.2	1.8	1.4	1.0
MD_W = Mission Dependency Within a Command's AoR					

Figure 1. NAVFAC Mission Intra-dependency Matrix (Dempsey, 2006)

MISSION INTER-DEPENDENCY SCORE					
MD_B		Q3: Interruptability			
		Immediate (24/7)	Brief (min/hrs)	Short (<7days)	Prolonged (>7days)
Q4: Replaceability	Impossible	4.0	3.6	3.2	2.8
	Extremely Difficult	3.4	3.0	2.6	2.2
	Difficult	2.8	2.4	2.0	1.6
	Possible	2.2	1.8	1.4	1.0
MD_B = Mission Dependency Between Commands					

Figure 2. NAVFAC Mission Inter-dependency Score Matrix (Dempsey, 2006)

The Air Force adopted the MDI as a performance measure used in performing portfolio management after collaboration with the Navy. However, the Air Force did not adopt the full version of the Navy's MDI determination methodology. As described above, the Navy's methodology requires it to conduct interviews of stakeholders at each installation to accurately determine intra-dependency and inter-dependency scores for each asset. The Air Force decided that this process was too costly and complex (Madaus, 2009). Instead, the Air Force assigned a predetermined MDI to each Air Force real property Category Code (CATCODE). As such, there would be no need to conduct extensive interviews across the Air Force's 185 installations worldwidewide. As the Navy and Air Force CATCODES did not match for facilities with similar functions, the Air Force decided to relate them by means of Facility Analysis Codes (FACs), which are uniform across the Department of Defense (DOD) (Madaus, 2009). A proof-of-concept was conducted at Langley AFB and Fairchild AFB before the Air Force-wide adoption. The study was deemed successful and the MDI performance measure was adopted across the Air Force (Antelman, 2008). The Air Force expected that after enterprise-wide adoption, installations and MAJCOMs would question the accuracy of the MDI as it applies to some of their specific facilities (Madaus, 2009). Therefore, the Air Force Civil Engineer Center (AFCEC) published the MDI Refinement Playbook in 2014 to establish a standard adjudication process for the MDI (Smith, 2016). As of 2015, MDIs of more than 1,000 Air Force facilities had been submitted for this refinement process and adjudicated (Smith, 2016) to align the MDIs with the expectations of installation stakeholders.

2.3. The Air Force Portfolio Selection Procedure Challenges

The research The Mission Dependency Index: Fallacies and Misuses, Kujawski & Miller (2009) descibe several inherent fallacies regarding how the Mission Dependency Index is derived and applied by the Navy and adopted by the Air Force. First, the MDI uses Operational Risk Management (ORM) techniques of probability and severity and applies them to facilities in terms of interruptability, relocateability, and replaceability. However, Kujawski & Miller state that the MDI matrix expresses risk quantitatively, which was not the intent of the Navy's ORM approach (OPNAVINST 3500.39B, year) that expresses risk qualitatively. It follows then that numbers in the matrix are ordinal, not rational, and cannot be added or multiplied. The MDI, however, does exactly that by using the numbers from the matrix in an algebraic equation. Moreover, the MDI matrix does not include a scale for the probability of risk occurrence. Kujawski & Miller state that according to ORM, any risk assessment tool needs to measure a probability of a mishap to qualify as such. Second, the MDI does not take into account workarounds. For example, interruptability and relocateability of a typical steam plant are characterized as "briefly (≤ 24 hrs)" and "impossible", respectively. This does not account for the workarounds that can be put in place to deal with a problem like using ceramic heaters, moving airmen from dorms to hotels, etc. Third, the MDI does not always result in the prioritization of funding for most critical assets. For example, the MDw variable is 2.8 for a remote air-traffic control center and 3.6 for a steam plant on a military base in a non-combat zone. Any reasonable person would agree that the remote air-traffic control center is more important and that the operational risk of its inoperability is higher than that of a steam plant, but the MDI method ranks it lower because MDI prioritizes the function of a building over its overall mission. Finally, Kujawski & Miller state that the MDI equation is flawed and can produce nonsensical results. For example, the equation is not defined if $n = 0$ and is negative if MDw = 0, both of which are realistic scenarios.

In addition to the MDI structural defects associated with how it was derived and applied, there are issues that arose when the Air Force adopted the MDI by merely relating the Navy facility MDI scores to the Air Force facility CATCODES. First, there is an incentive for installations to utilize the MDI refinement process if they believe that an MDI score of a facility is too low. However, there is no incentive to lower a score of the facility if installations believe its score is too high. This is called MDI inflation (Smith, 2016). For example, all airfield runways are automatically assigned an MDI score of 99. However, some installations have more than one runway. Ancillary runways on those installations may not be utilized at all but would still receive an MDI score of 99. This is also true about various pads and ramps on airfields. Millions of dollars are spent every year on repairing pads and ramps which get little or no use at all only because they are never removed from a list of real property assets or their MDI scores are never reviewed. Thus, due to this inflation, the Air Force ends up with a number of facilities with inaccurate MDI scores.

Second, facilities at installations with missions that are different from standard operational installations get assigned lower MDI scores (Nichols, 2015). For example, the MDI scores for facilities that belong to Air Education and Training Command (AETC) and Air Force Global Strike Command (AFGSC) can be misrepresented. In fact, as of 2015, facilities belonging to AFGSC were submitted for refinement the most, as shown in Figure 3. Third, incorrect Air Force assumptions behind the MDI methodology lead to inaccurate MDI scores (Nichols, 2015). For example, the Air Force assumes that Navy facilities are equivalent to Air Force facilities. This is a stretch as the Navy's mission is very different from the mission of the

Air Force. Therefore, to perform its mission, the Navy requires a set of facilities distinct from Air Force facilities. In addition, the same Navy facilities may not be as critical for its mission as they would be for the Air Force.

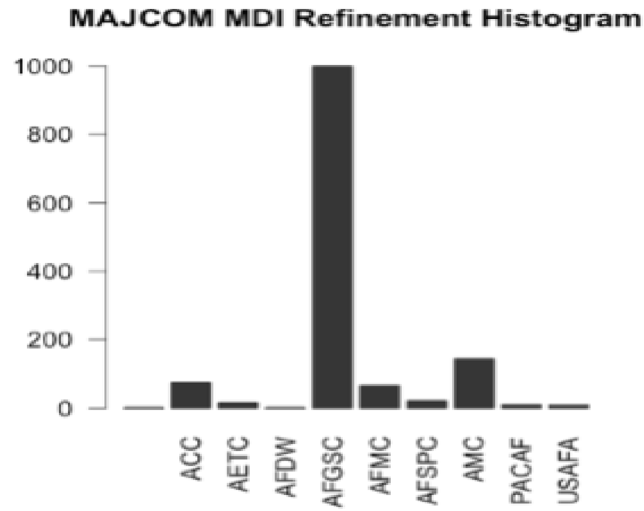

Figure 3. MAJCOM MDI Refinement Histogram (Smith, 2016)

In a Delphi study, Nichols (2015) asked various Air Force subject matter experts (SMEs) to share their concerns regarding the MDI. A major flaw that was identified by these experts in the first round of the Delphi study was MDI's inability to properly identify non-flightline mission assets and the facilities used to support them (Nichols, 2015). This is the same issue that CE leadership at Edwards AFB is concerned about. SMEs in the Delphi study recommended delegating decision authority to each base's Facility Utilization Board (FUB).

To tackle the MDI deficiencies associated with CATCODES, in fiscal year 2018 the Air Force Installation and Mission Support Center, working with Jacobs Engineering Group Inc., conducted an MDI re-baselining effort which introduced the tactical MDI. "Tactical MDI allowed wing commanders to influence their facility's MDI scores (and therefore project prioritization and funding) by gathering input from their group and squadron commanders about what facilities are the most critical for mission execution" (Weniger, 2018). As a result of this effort, CATCODE MDI scores of some facilities were retired to be replaced by tactical MDI scores, while others, mainly utilities, kept their CATCODE MDI scores. Starting with fiscal year 2020, Air Force bases use tactical MDI for some facilities along with CATCODE MDI for others when deriving technical scores for projects submitted for the Integrated Priority List (IPL).

Due to these described deficiencies, there is a need to find an alternative to the current Air Force decision support framework. As was described in the introduction section, in the fiscal year 2020, AFCEC partially transferred decision-making authority for FSRM projects to the FUB. The challenge now is to determine what kind of decision support framework the FUB should use to decide which projects to fund.

2.4. Value Focused Thinking

VFT is a methodology used for gathering data about inputs of a process to generate a model that ties strategic goals to routine operations (Keeney, 1992). In other words, VFT ensures that proposals that are selected for execution are the ones that would contribute most to achieving the strategic goals of the decision-maker. The main principle of VFT is ensuring that choices made by a decision-maker are in line with the decision-maker's values. After all, if an initiative is not aligned with decision-maker's values, then there is no reason to make it into a project. VFT achieves this alignment by means of a Value Hierarchy, which is a tiered decision support model that shows relationships between broad goals of a decision-maker, values that are derived from those goals, and measures used to evaluate the degree of value attainment (Shoviak, 2001).

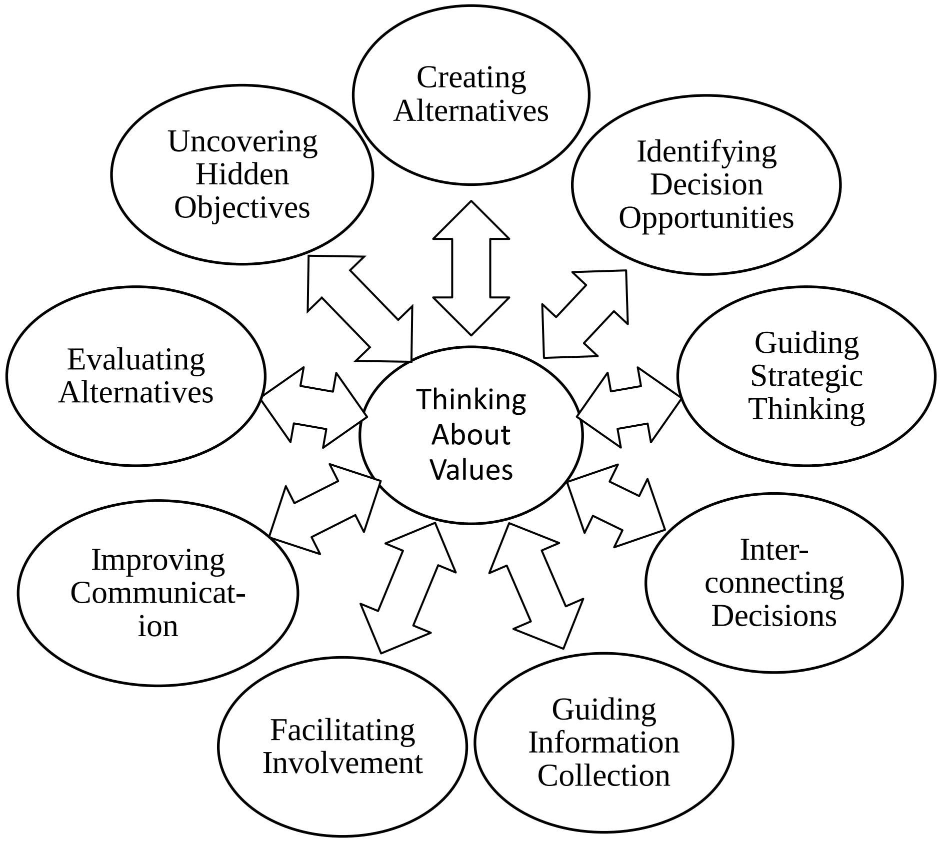

Figure 4. Overview of Value Focused Thinking (Keeney, 1992)

As can be seen in Figure 4, there are many advantages to using VFT. It provides a clear vector for all of the decision-maker's actions. One advantage that must be emphasized is that VFT improves communication. Stakeholders are clearly able to see values according to which their proposals will be judged. This is especially important in a governmental organization where decision transparency and defendability are paramount.

2.5. Steps to Building a VFT based Decision Support Framework

There are ten steps to building a decision support framework. This section explains each of these steps. Figure 5 presents a flow-chart that depicts the sequential order of the 10-step VFT process.

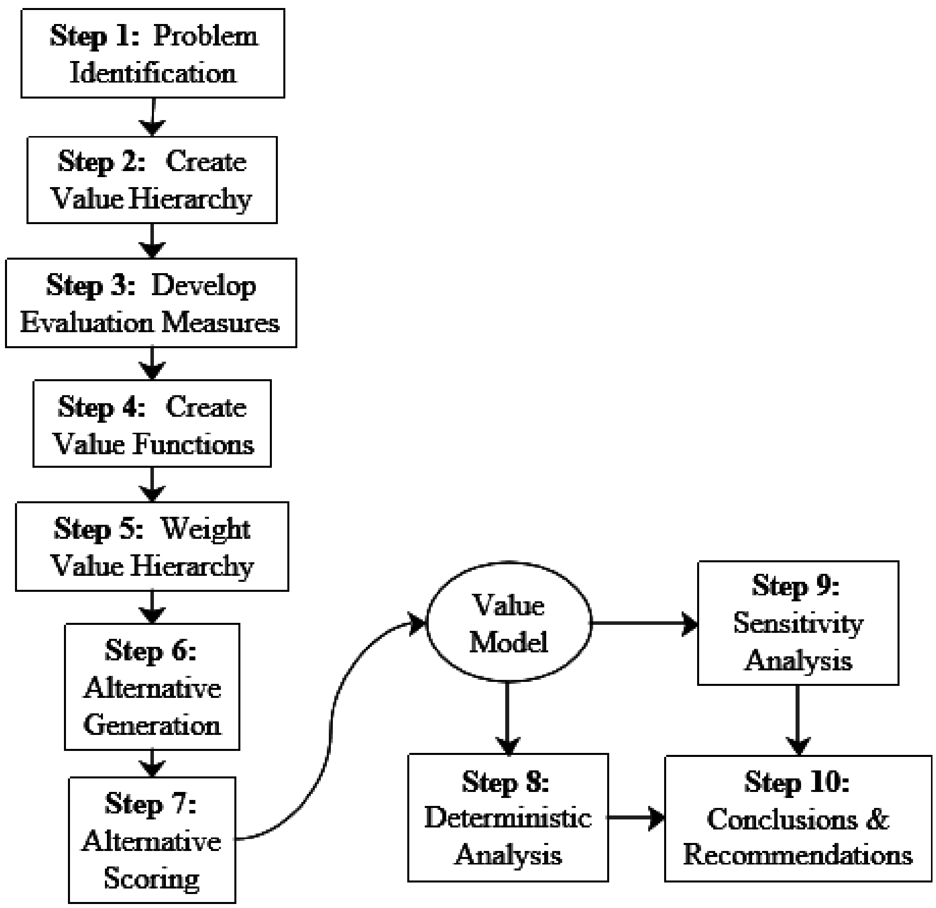

Figure 5. Steps in Building VFT Based Decision Support Framework (Shoviak, 2001, p.63)

Step 1: Problem Identification

This step outlines the issue to be resolved. It describes a problem that prompted a decision-maker to turn to a decision support framework in the first place.

Step 2: Create Value Hierarchy

The value hierarchy is a hierarchical chart that depicts the breakdown of the values of a decision-maker from general to specific related to the specific problem being addressed. It is made up of levels or tiers. The top tier depicts a single overarching objective of a decision-maker. Lower tiers break down that overarching goal into broad values of that decision-maker. Every lower tier of values breaks down upper values in order to more specifically define what they represent to a decision-maker. The bottom tier of a hierarchy consists of measures. The measures are used to quantify how well a given proposal satisfies any given value and thus help differentiate between various proposals.

Desirable properties of value hierarchies consist of completeness, non-redundancy, decomposability, operability, and small size (Kirkwood, 1997). *Completeness* means that the totality of values in every tier of a value hierarchy has to add up to represent the same overarching goal, i.e., the sum of tier 3 values is merely a further refined sum of tier 2 values and so forth. The property of *Non-redundancy* means that values in the hierarchy need to be mutually exclusive to avoid unintentionally assigning more weight to a value in decision making than it deserves. *Decomposability* describes the property of a value where its score does not affect or is not affected by a score assigned to a separate value. In other words, all the values need to be independent of each other. *Operability* means that values have to be understandable by a layperson. This is especially important in public organizations where organizational leadership decisions are subject to questioning by the public. The *Small size* property of a value hierarchy has to do with making the decision support framework workable. It cannot be too big and too cumbersome for practical use.

All value hierarchies have to start with specifying the overarching objective. The overarching objective is the problem being addressed (Jurk, 2002). The overarching objective is followed by tier 1 values, which are overarching values of the decision-maker. An obvious source of the decision-maker's overarching values are the governing documents of an organization. For organizations making up the U.S. Air Force, the sources of overarching values are the Air Force Instructions and lower-level guidence documents derived from the instructions. The overarching values are customarily derived from such documented principles. However, if such a documented set of principles does not exist, then major values can be determined by stakeholder discussions. Deriving values from existing documented principles makes them more defendable and therefore such a "degree of interaction" is called a "gold standard". The "Silver Standard" describes values derived from stakeholder interviews and discussions (Parnell, 2007). The value tiers below tier 1 break down corresponding upper values to more precisely define what they represent to the decision-maker (Jurk, 2002).

Step 3: Develop Evaluation Measures

When a value cannot be broken down further into sub-values, the next step is to determine the measures. The last tier of any value branch contains measures. Measures are used to indicate the "…degree of attainment of objectives. Evaluation measures allow an unambiguous rating of how well an alternative does with respect to each [value]" (Kirkwood, 1997, p.24). There could be more than one measure per value.

Evaluation measures may have natural or constructed scales. A natural scale is objective; it "has a common interpretation to everyone" (Kirkwood, 1997, p.25). Examples of natural scales are seconds for time, meters for distance, and kilograms for mass. Constructed scales are "developed specifically for a given decision context" (Keeney, 1992, p.102). They are subjective and thus more controversial than natural scales. Examples of constructed scales are those consisting of categories such as Immediate, Brief, Short, and Prolonged to describe levels of Interruptability for determining MDI.

Evaluation measures need to possess the properties of measurability, operationality, understandability, and commonality (Keeney, 1992). Measurability "defines the associated [value] in more detail than that provided by the [value] alone" (Keeney, 1992, p.113). Measurability means that the scope of a measure must be limited to what the decision-maker is concerned with. The scope of a measure must not include any more meaning than required for decision-making. Operationality means a measure must "provide a sound basis for value judgments" concerning the "desirability of the various degrees to which [that value] might be achieved" (Keeney, 1992, p.114). It means that every level, degree, etc., on the measure scale must indicate a distinct impact on decision-making. Understandability implies there is "no loss of information when one person assigns [a measure] level to describe a consequence and another person interprets that [measure] level" (Keeney, 1992, p.116). It means that all possible stakeholders must have a common agreement on what a measure represents. Finally, a measure must also be common to all possible alternatives. It means that a decision cannot be made unless all the alternatives possess the same property that is to be evaluated.

Step 4: Create Value Functions

The measures indicate the degree of attainment of objectives, but they often do that using different scales. The purpose of the Value Functions is to standardize scores of varying scales by converting them into generic and uniform scores of *value*. The scale of value units is formed by giving the worst score across all the alternatives for a given measure a value score of zero and the best score across all the alternatives a value score of one (Kirkwood, 1997). In statistics, this adjustment of a given measure's scale to a scale between zero and one is called normalization. This normalization of scores for each measure is achieved through the use of Single-Dimensional Value Functions (SDVF). SDVFs can be linear, exponential, or discrete (Kirkwood, 1997). The type is determined by stakeholders involved in SDVF development.

Step 5: Weight Value Hierarchy

The decision-maker's values shown in the hierarchy are not all of the same importance. Some values are more important than others. We express this difference in importance by assigning each value in a hierarchy a weight, which is determined by the decision-maker (Jurk, 2002). The weights of the values in the same tier and within the same branch add up to one. These weights are called local weights because they are independent of weights assigned to upper or lower tier values in the hierarchy. The global weight of a value, on the other hand, is determined by multiplying the local weight of an individual value by the local weights of all values in the branch preceding it. The global weight shows how much importance is placed on a value when considering all value branches in the same tier (Jurk, 2002).

Step 6: Alternative Generation

This is the step where competing proposals are generated before they are scored against the created value hierarchy. Alternative Focused Thinking metholodogy limits creativity. People tend to identify a needlessly narrow range of alternatives for a given problem. Moreover, the identified alternatives tend to be the obvious ones (Keeney, 1992). One of the advantages of VFT methodology is in encouraging creativity in developing project proposals guided by the knowledge of the decision-maker's values. In some cases, the generation of alternatives takes place outside of the organization (Jurk, 2002).

Step 7: Score the Alternatives

The scoring of alternatives is the responsibility of the decision-maker (Jurk, 2002). Although VFT is a great tool for defining the importance of a project for a decision-maker, using it to score project alternatives could be a lengthy process compared to other methods of decision-making. Significant amount of time could be spent gathering data to evaluate the measures of competing proposals. Therefore, a decision-maker could task a forum of subject matter experts with scoring and ranking the proposals. The decision-maker could delegate further by giving the job of approving the project proposals to a board comprised of local organizational stakeholders. The board members could review the scoring and ranking of the projects and send their recommendations to the decision-maker for final review and approval (Jurk, 2002).

Step 8: Deterministic analysis

Deterministic analysis is the process of aggregating individual measure scores into a single score for a given alternative. This is done by multiplying the value score for each measure by its global weight and then adding or multiplying the resultant weighted scores. There are two primary value function types used in VFT: additive and multiplicative (Kirkwood, 1997). The additive value function is simplistic and encourages easy, detailed sensitivity analysis; it is also the most commonly used type in decision analysis practice (Kirkwood, 1997). Its mathematical representation is shown by Equation 2.

$$v(x) = \sum_{i=1}^{n} \lambda_i \cdot v_i \cdot (x_i) \qquad (2)$$

$v_x = Combined\ value\ score\ of\ all\ the\ measures\ in\ the\ hierarchy$

$v_i(x_i)$ = *Score of a measure converted into units of value*

$\lambda_i = Global\ weight\ assigned\ to\ a\ given\ measure$

Step 9: Sensitivity Analysis

Sensitivity analysis shows the "impact on the ranking of alternatives [based on] changes in the modeling assumptions" (Kirkwood, 1997). Sensitivity analysis is conducted by performing deterministic analysis for a range of weights of a given value in the hierarchy to find out how the aggregate value score of an alternative changes. Weights and corresponding aggregate value scores for each alternative are plotted on a graph. This graph shows how the aggregate value score of each alternative changes with a change in a given value's weight. All alternatives are plotted on the same graph, which helps to show how their ranking changes depending on changes in a given value's weight. It helps decision-makers visualize how the ranking of project alternatives changes with a change in the weight of a value. This visualization is especially helpful if there is a disagreement between stakeholders on weights assigned to one or several values. It is preferred to perform sensitivity analysis by changing weights assigned to tier 1 values because changes in the weights of lower-tier values do not significantly alter the aggregate value score.

Step 10: Conclusions and Recommendations

The alternatives are ranked as part of deterministic analysis. The ranking is presented to the decision-maker. The decision-maker reviews and approves, disapproves, or modifies the ranking of alternatives (Jurk, 2002).

2.6. Summary

This chapter discussed the historical background of Air Force asset management and its guiding principles. It also described how AFCEC performs FSRM project selection. It explained how the MDI score is determined and the challenges associated with its use. It also described the overall challenges associated with the current AFCEC FSRM project portfolio selection. VFT was offered as an alternative decision support methodology that remedies challenges associated with the AFCEC project selection method. This chapter also described all the steps needed to develop a value hierarchy and use the VFT process.

Chapter III. Methodology

This chapter discusses the actual steps that were taken and discussions that were held in order to apply the Value Focused Thinking (VFT) methodology to the creation of a decision support model for the Civil Engineering Group (CEG). The chapter starts with a discussion of how the VFT methodology was introduced to CEG panel members. The next two sections detail how feedback was collected from the panel members, then describes the panel member experiences and job titles. The chapter proceeds into the section desribing analysis of the VFT application, which details the actual process that the panel went through to conduct the discussions. Then, the next section describes threats to validity of the model breaks down apparent risks to its soundness. A detailed description of the panel discussion of steps 1 through 5 of the VFT process that lead to creation of the decision support model is given in the subsequent sections of this chapter.

3.1. Value Focused Thinking Methodology

This study intends to devise a decision support model by accomplishing steps 1 through 10 of the VFT methodology. To achieve this goal, a panel consisting of seven members was selected. The goal was to explain the advantages of VFT and the steps involved in VFT methodology to the panel members and to have them devise a decision support model utilizing this methodology. The model would be used to select Facility Sustainment Restoration and Modernization (FSRM) projects to be accomplished using decentralized funding received by Edwards AFB from AFCEC. As an initial step, the author distributed among the panel members the example shown as Appendix B to illustrate how the VFT methodology is used to come up with a decision support model. The example guides readers through steps 1 through 6 of the

VFT methodology. The example was based on one put together by Jurk (2002) in his reserarch. The example was chosen for its simplicity and completeness. The author in that example uses the VFT methodology to devise a decision support model to help him select a truck for purchase based on properties he personally values in a truck. He follows the steps of the VFT methodology to develop a value hierarchy that includes measures and assigns weights to those values and measures. Panel members were asked to independently review the example before the in-person meeting to develop a better understanding of the VFT approach. The panel members were also asked to think about values they would like to use in the FSRM project selection model.

3.2. Data Collection

Due to COVID-19 and busy schedules, the panel could not be assembled in a single conference room; therefore, a separate discussion was held with each panel member. At each initial discussion, the author went over the VFT methodology and asked a series of guiding questions related to each step of the VFT process. These questions are listed in Table 7.

Table 7. Guiding Questions Asked of the 412 CEG Panel Members

Step 1- Problem Identification
What is the problem we are trying to resolve?
Step 2 – Create Value Hierarchy
What objective are we trying to achieve?
What principles are we guided by when selecting projects for funding?
What is your interpretation/breakdown of Tier 1 values based on your experience?
Step 3 – Develop Evaluation Measures
How would you measure the degree of attainment of each value in order to differentiate alternatives with respect to each other?
Step 4 – Create Value Functions
How would you normalize disparate measures into common units of value?
Step 5 – Weight the Value Hierarchy
What weights would you assign to values based on your experience of their importance?

3.3. 412th CEG Panel Composition

All panel members were members of the 412th Civil Engineer Group. They were selected based on their experience, seniority within the organization, and length of service in the organization. To qualify for a seat on the panel, a member had to have a minimum of 15 years of experience with at least 5 years within 412th CEG and have a working knowledge of project programming and funding fundamentals. The panel was made up of only 412th CEG members because the intent of the research was to devise a decision support tool that takes into consideration requirements unique to Edwards AFB.

3.4. Analysis of VFT Application

The inability to gather all the panel members together in the same location required several rounds of discussions. The initial round of discussions resulted in seven separate value hierarchies that were remarkably similar but not quite the same. Therefore, there was a need to unify all of the hierarchies into one that all the panel members could have a consensus on.

During the subsequent rounds of discussions, feedback regarding the unified hierarchy and measures was obtained. The intent was to determine if the combined hierarchy and measures were agreeable to all the panel members and were in line with their individual feedback. Once consensus on the VFT hierarchy and measures was achieved, panel members were asked to evaluate the combined hierarchy from the perspective of completeness, non-redundancy, decomposability, operability, and small size. All panel members agreed that the unified hierarchy satisfied all of the aforementioned desirable properties.

3.5. Threats to Validity of the Model

A threat to the validity of the model is the assumption that a panel consisting of 412th Civil Engineering Group project programmers and leadership are best suited to interpret Air Force publications on behalf of the installation commander who is ultimately responsible for making project funding decisions. Another threat to validity is an assumption that any constructed and proxy measures that the panel members agree on using in the model would be acceptable for the installation commander as true reflections of given value attainment.

3.6. Step 1: Problem Identification

This study idea originated within Edwards AFB 412th Civil Engineering Group. The 412th CEG leadership was asked to define an issue that they saw as pressing, resolving which would have a positive local impact on the base. A common theme among the complaints was that the current mechanism of determining which projects to fund heavily favored facilities with high MDI scores and made it virtually impossible to fund repair and maintenance projects for all other facilities. The leadership requested that an alternative method of sorting projects for funding be devised that would ensure a more balanced distribution of the funding. This new model needed to be based on a proven and widely accepted methodology; be simple to use, so as not to consume a lot of time and effort; and be transparent, repeatable, and defendable. Research indicated that VFT satisfied all of the aforementioned criteria; therefore, it was selected as a means of devising the requested decision support model. If successful, this model could be used to rank projects in line for decentralized funding which is distributed locally at the Installation Commander level. Decentralized funds were established by the Office of the Air Force Deputy Chief of Staff for Logistics, Engineering, and Force Protection in the form of Air Force Guidance Memorandum to AFI 32-1032, Planning and Programming Appropriated Fund Maintenance, Repair, and Construction Projects, on 23 May 2018. These funds give bases more freedom in determining which projects to fund and are a perfect candidate for utilizing the decision support model that will be established by this research.

Step 1 of the process is to identify the problem for the model to tackle. During the discussion, the panel members agreed that the problem that initiated the research was obvious to all of them. They all agreed that the problem was that the AFCEC model of sorting and funding projects was not ideal because it disproportionately favored facilities with a high MDI scores. The installation commander, as the decision-maker, requires a decision support mechanism that would support the selection of projects which are in line with his or her values. Therefore, a new decision support model was needed that delivered a balanced portfolio of projects. The following section discusses step 2 of the process of constructing a VFT-based decision support model.

3.7. Step 2: Create Value Hierarchy

To create the value hierarchy, members of the panel had to agree on the fundamental objective that the decision-maker was trying to achieve. Here, again, the answer was obvious to the panel members and they unanimously stated that the goal was to choose which facilities should be prioritized for Sustainment, Restoration and Modernization and then executed using decentralized funds received by the base. The next step was to brainstorm and agree on tier 1 values for the hierarchy. Tier 1 contains the overarching values of the decision-maker and should be derived from the governing documents of the organization. Deriving tier 1 values from such documents would constitute a "gold standard" and lend the hierarchy legitimacy and thus acceptance by stakeholders. Therefore, the panel turned to Air Force publications for guidance in determining these values. Panel members reviewed Air Force Instruction 32-1032, Air Force Instruction 32-1001, and Air Force Policy Directive 32-10. See Appendix F for extracts of relevant paragraphs from the publications. Based on these Air Force publications and based on their personal experiences of working with decision-makers, panel members agreed that there are three reoccurring responsibilities that the Air Force guides installations to accomplish. Panel members were unanimous in stating that the following three responsibilities should form the tier 1 values of the VFT hierarchy: Support for mission capability; Support for people by improving their working and living conditions (in other words, support of quality of life on the base); and Ensuring the functionality of the facilities.

Next, each panel member had to decide whether to decompose tier 1 values into components. Panel members had to leverage their experiences to interpret what tier 1 values would mean in practice at their organization's level of decision-making. Some panel members suggested that the tier 1 value of Support Mission Capability should be separated into two tier 2 values of Support for the Air Force Mission and Support for Local Missions like Security Forces. However, such a breakdown was rejected by most panel members. They stated that there was no practical way to characterize a facility's support for a local mission versus the Air Force mission. It was agreed that all facilities on base perform Air Force missions but those missions were of varying importance to the Air Force. Panel members thus concluded that the tier 1 value of Support Mission Capability could not be separated into smaller components.

The tier 1 value of Ensure Functionality of the Facilities generated the liveliest deliberation. Some panel members wanted to break this value down into building components like fire suppression system, electrical system, HVAC system, etc. Other panel members stated that there was no need to break the tier 1 value into separate components because there already exists a procedure that evaluates the robustness of different facility systems and combines them into a unified, normalized score for each facility. That procedure produces the Facility Condition Index. In the end, it was agreed that the tier 1 value of Ensuring Functionality of Facilities would not be decomposed into tier 2 values and that FCI will be used as a measure for this value.

All the panel members agreed that the tier 1 value of Support Quality of Life on Base was necessary. In fact, having the quality of life as a separate value in decision making is the major difference that sets the VFT model apart from the AFCEC model. However, although panel members agreed that Quality of Life on Base needed to be one of the values in the hierarchy, some were not sure if it should be a separate tier 1 value. There were suggestions to include Quality of Life as a tier 2 value under the tier 1 value of Ensuring Functionality of the Facilities, or vice versa. The argument was that the robustness of facilities directly correlated to the quality of life in those facilities; thus, it would be wrong to separate these two. The deliberation, in fact, was over the definition of this value. Other panel members argued that it should be a standalone tier 1 value. Panel members discussed that given two buildings, say a hangar and a gym, with identical condition scores, which building would the majority of the base populace most likely prefer to have repaired. Based on experience, panel members agreed that the majority on base would prefer to repair the gym over the hangar with an identical FCI score. It was decided that the value of Quality of Life would be used to make such a distinction. Panel members established that the value of Quality of Life on Base is related to the purpose of the buildings (i.e., its use) rather than its condition. Thus, the argument to include Quality of Life as a standalone tier 1 value prevailed. The resultant value hierarchy without the measures is shown in Figure 6.

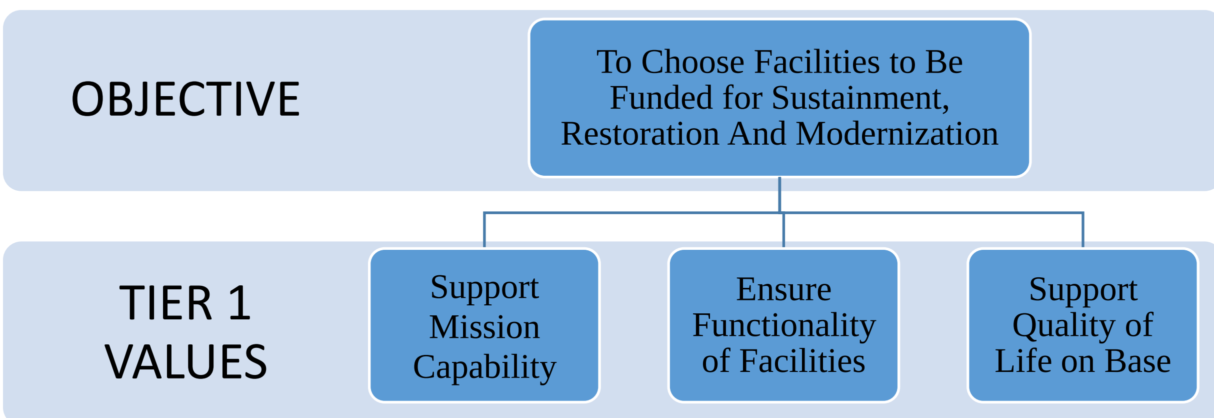

Figure 6. Resultant Value Hierarchy

3.8. Step 3: Develop Evaluation Measures

Panel members agreed that there was no need to break down tier 1 values further into tier 2 values. Therefore, tier 1 values would be directly followed by measures. At first, some panel members suggested that the value of Support Mission Capability should be evaluated using measures of Interruptability, Redundancy, Replaceability, and Number of Missions Affected. However, other panel members disagreed. They argued that it would take too much time and effort to evaluate every facility using these measures. They also argued that the existing MDI was derived using the aforementioned four criteria; therefore, there was no need to include it twice. Moreover, panel members wanted to ensure that the hierarchy is simple to use. Simplicity in understanding and using the VFT hierarchy was one of the goals the panel members set out to achieve from the start of the discussion.

All panel members agreed that the best measure for the value of Ensure Functionality of Facilities is the FCI because it is a result of a comprehensive and robust process of facility condition assessment. The use of FCI as a measure would contribute to model transparency and defensibility. Moreover, using FCI as a measure would greatly simplify the use of the model and reduce the amount of effort needed to score the projects. It would allow a single programmer to evaluate numerous projects in a short period of time.

When it comes to the value of Support Quality of Life on Base, there is not a ready "off the shelf" measure that could be used to score potential projects. Panel members brainstormed various possible measures. Some suggested that the number of people that use the facility could be used as a possible measure. The more people worked in and visited the facility the more important they claimed it would be from a quality of life perspective. Others stated that although this idea had merit, it would be challenging to collect the information and the number of people using the facility does not necessarily correlate with the base populace's view of the facility's importance from a quality of life perspective.

They reasoned that a measure for this value had to be able to differentiate between levels of contribution to the quality of life on the base for facilities such as a hangar and a gym. Since panel members established that this value was related to the function of a facility, it was agreed that each type of building could be assigned a permanent score based on its function, just like

MDI but for quality of life. Panel members could not think of any ready measures like MDI and FCI that were applicable in this case. The literature was reviewed to investigate if a suitable measure existed. Although a few variatiions of indexes dedicated to measuring quality of life were found, they all were related to gaging levels of life-satisfaction across countries. No measure of quality of life was found related to facilities on military bases. Therefore, panel members resolved to create such an index. They agreed to call this measure a Quality of Life Index (QLI). It would be a so-called constructed measure "developed specifically for a given decision context" (Keeney, 1992). QLI would measure the level of the facility's contribution to the quality of life on base on a scale from 0 to 5. Each numeric score on the scale was assigned an equivalent qualitative score, see Table 8. The use of a numeric scale for QLI along with its qualitative equivalent makes the scores less ambiguous. Panel members decided that the only question that should be asked of the decisions-maker when scoring a facility using the measure of QLI is: What score would you assign this facility based on your opinion of its perceived contribution to the quality of life on base? They reasoned that this question is sufficient because the measure truly only relates to the base populace's emotional perception of the importance of a facility to quality of life.

Table 8. QLI Constructed Measurement Scale and Descriptions of the Scores

QLI SCORE	DESCRIPTION/QUALITATIVE SCORE
0	Facility's contribution to the quality of life on base is None
1	Facility's contribution to the quality of life on base is Minimal
2	Facility's contribution to the quality of life on base is Low
3	Facility's contribution to the quality of life on base is Moderate
4	Facility's contribution to the quality of life on base is High
5	Facility's contribution to the quality of life on base is Excessive

Panel members agreed that to make the measure widely acceptable facilities have to be assigned quality of life scores directly by the base populace. It could be achieved by conducting a base-wide survey of base military and civilian populations. However, conducting a base-wide survey of both military and the civilian populace was not possible at the time and could be a subject of future research. Therefore, leveraging their experiences, panel members agreed to rate facilities themselves and determine the respective QLI.

The next challenge was to establish types of facilities on base. A panel member suggested that UFC 4-020-01, DoD Security Engineering Facilities Planning Manual, Table 3-1 Common Facility Types, could be used to identify typical types of facilities on base. This table is shown in Appendix D. The table establishes typical facilities found at an Air Force base for purposes of evaluating them for ATFP requirements. Each panel member leveraged their experience to rate facilities listed in UFC 4-020-01 Table 3-1 according to their contribution to the quality of life on base on a scale from zero to five. Then, the scores were averaged and rounded for all the facilities on the list. The goal of this exercise was to achieve consensus among the panel members. Averaging and rounding of the QLI scores served as means of achieving that consensus. The resultant average QLI scores can be seen in Table 9. See Appendix E for scores assigned to the facilities by individual panel members. Table 9 does not contain all the facilities listed in UFC 4-020-01 Table 3-1 because some of the facilities listed in Table 3-1 use NAF (Non-Appropriated Funds) funds and do not qualify for decentralized AFCEC funding.

Table 9. Average QLI Scores Assigned by Panel Members to Typical Base Facilities

FACILITY	QLI SCORE	FACILITY	QLI SCORE
Brigade, Battalion, Company Headquarters	2	Craft Centers	3
Airfield Operations Facility	3	Enlisted Barracks/Dormitories	5
Aviation Unit Operations Facility	2	Chapel	4
Field Operations Facility	2	Auditorium	3
Ship Operations Facility	2	Gymnasium	5
Emergency Operations Facility	3	Theater	4
Fire/Police Station	4	Alert Systems, Forces, and Facilities	3
National Guard/Reserve Centers	2	Equipment Maintenance Facilities	2
Cargo Handling Office	2	Aviation Maintenance Facilities	3
Dispatch Building	2	Motor Pools	2
Courtroom	3	Aicraft Parking Areas	2
General Administrative Facility	3	Magazines	2
Education Center	4	Arms Rooms	2
Religious Education Center	4	Weapons Maintenance Facilities	2
Community Service Center	5	Petroleum, Oils, and Lubricants Storage Facilities	1
Child Development Center	5	Research and Development Facilities	2
Drug/Alcohol Abuse Center	3	Warehouses	2
Red Cross Building	3	Utilieis and Substations	3

Figure 7 shows the final value hierarchy with assigned measures that was agreed upon by all the panel members. It consists of three tier 1 values and three measures with one measure per value. The following section discusses the assignment of weights to the values.

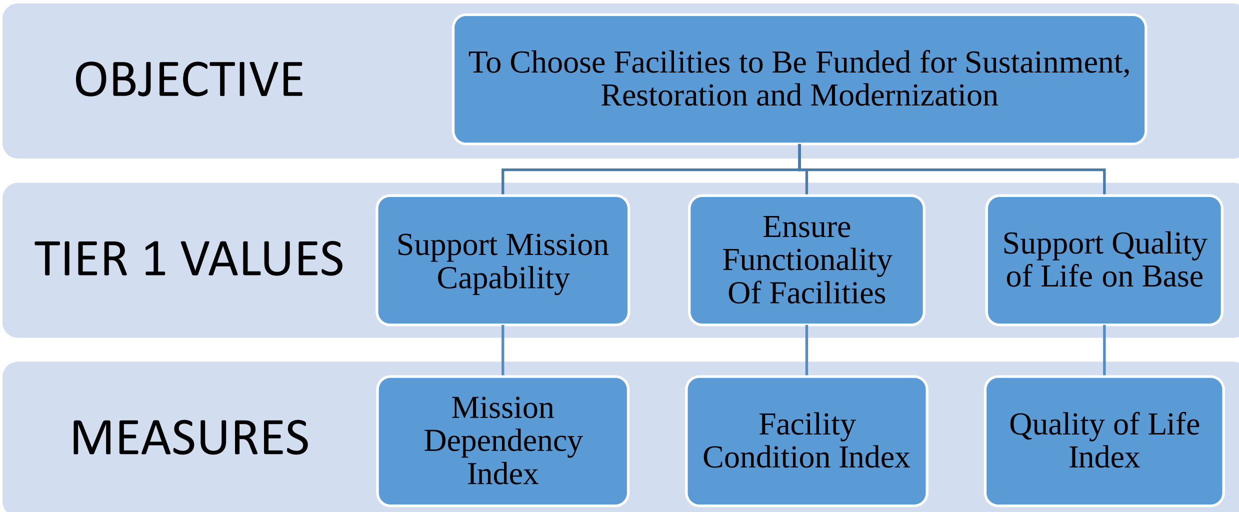

Figure 7. Final VFT Hierarchy with Assigned Measures

3.9. Step 4: Create Value Functions

Each measure in the value hierarchy has a distinct unit. To be able to combine these disparate units in the hierarchy, we need a way to convert them into common units of "value" on a scale from 0 to 1. Normalization of the scores into units of value is done by equating the most desirable score of a measure to 1 and the least desirable score of a measure to 0; thus, measure scores between least and most desirable will end up between 0 and 1. This conversion is done using single-dimensional value functions (SDVF). These functions could be continuous or categorical. The panel made a decision to use categorical functions for all measures as they are easier to use. Moreover, the differences between the use of continuous or categorical functions "is often not of practical significance" (Kirkwood, 1997). There is a degree of subjectivity in the process of assigning facilities FCI, MDI, and QLI scores, because those scores come from the judgment of assessing individuals. Figures 8, 9, and 10 show the SDVFs for the three measures. MDI and QLI scores in their respective SDVFs are directly proportional to corresponding values. This means an increase in a score is seen positively and therefore leads to a proportional increase in value. Scores in the SDVF for FCI, on the other hand, are inversely proportional to the values. A lower FCI score indicates a deteriorated facility with decreased functionality and thus needs to be prioritized for funding.

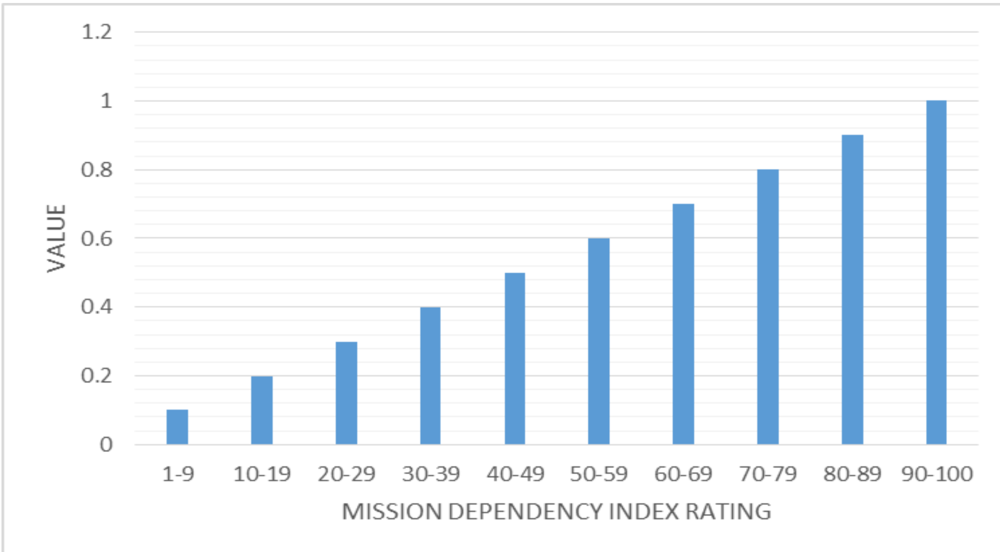

Figure 8. Single Dimensional Value Function for Measure of Mission Dependency Index

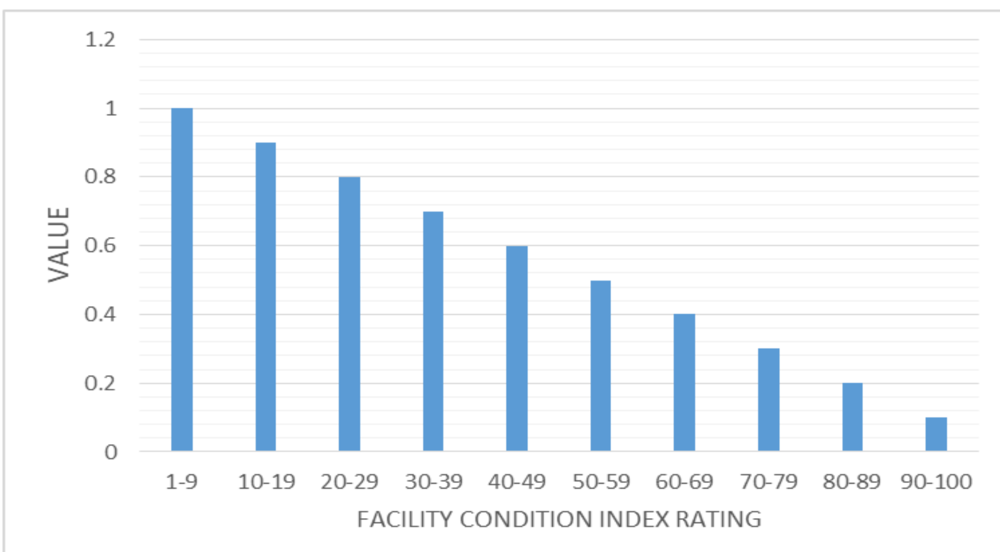

Figure 9. Single dimensional Value Function for Measure of Facility Condition Index

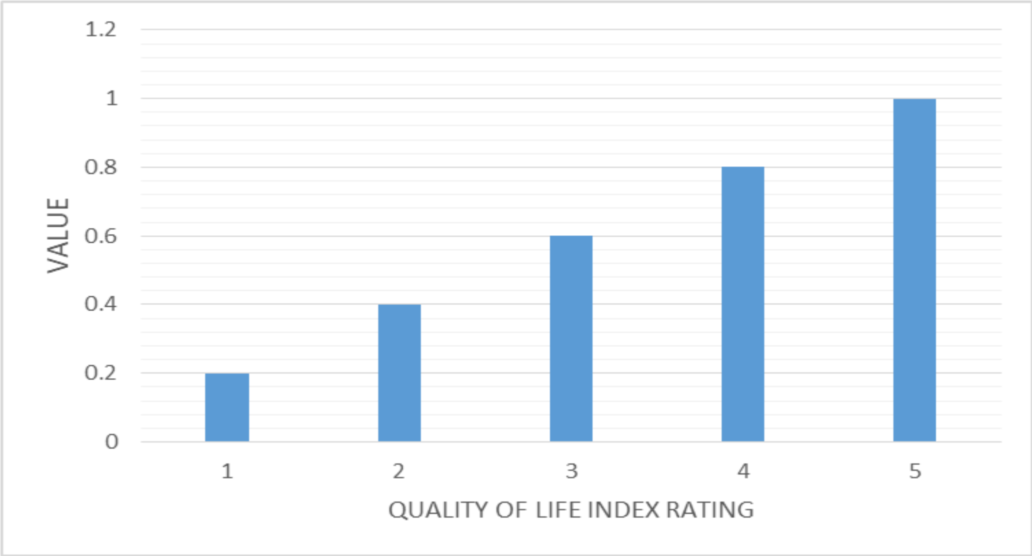

Figure 10. Single Dimensional Value Function for Measure of Quality of Life Index

3.10. Step 5: Weight Value Hierarchy

Step 5 calls for assigning weights to the values in the hierarchy. Air Force publications assign responsibility for distributing local FSRM funds to the installation commander who can delegate this job down to Base Civil Engineer (BCE). Therefore, the panel members were asked to leverage their experience to try and interpret which projects the installation commander would have prioritized and assign weights to the values accordingly. Panel members also agreed that weight assignments depend on the source of funding. AFCEC IPL funds, if distributed using the VFT hierarchy, would have prioritized the Air Force Mission-related projects and therefore the weight assigned to the value of Support Mission Capability would have been higher than weights assigned to the other two values. However, the research is mainly concerned with sorting projects to be funded by decentralized funds which are allocated locally. Local priorities do not align exactly with AFCEC priorities, thus the weight assignments would differ as well. Panel members reasoned that at the local level the installation commander and BCE prioritize projects that enhance the value of Quality of Life on Base and therefore this value should have the highest weight. Each panel member gave their opinion on what the weight assignments should be for every value. Those weights were then averaged. The resultant weights can be seen in Figure 11. The weight assigned to the value of Quality of Life on Base is significantly higher than the weights assigned to the other two values indicating the relative importance of this value for sorting projects for decentralized funding.

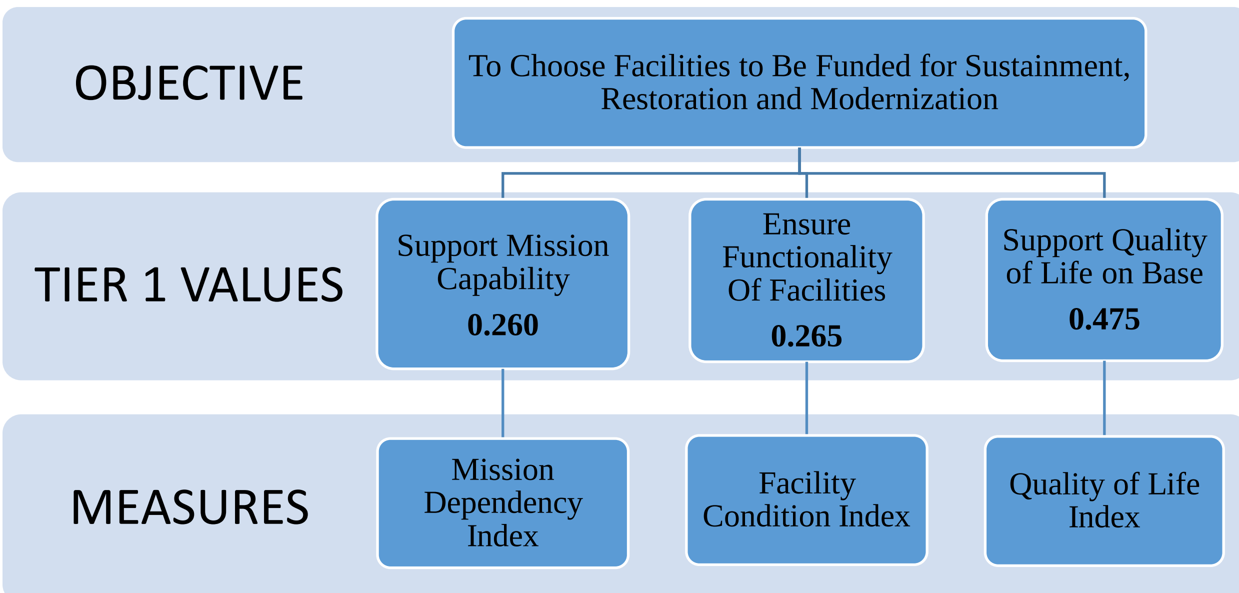

Figure 11. Final VFT Hierarchy with Assigned Value Weights

3.11. Summary

Chapter III discussed how the VFT methodology was applied in practice to resolve the research problem. After describing how the VFT methodology was explained to the panel members, the chapter went over how the data was collected and described the panel members' positions within the 412th CEG and their qualifications. It described practical challenges encountered in conducting the discussions and organizing data, as well as threats to the reliability of the resultant decision support model. The chapter also discussed how the panel accomplished steps 1 through 5 in building the VFT-based decision support model. Publications that serve as sources of the 412th CEG mission statement and consequently its tier 1 values were discussed. Deliberations of the panel members in determining which values would be included in the hierarchy were described. The rationale behind assigning particular measures to their respective values was explained. Finally, the selected value weights and value functions were presented. The next chapter discusses steps 6 through 9 of the VFT process.

Chapter IV. Results and Analysis

Chapter IV covers steps 7 to 9 of the Value Focused Thinking (VFT) process. Step 6 of the VFT process does not apply to 412th CEG. Base civil engineering does not generate projects; instead, it selects among tasks submitted for execution by various organizations on base or automatically generated by one of the asset management systems such as Builder and Paver. To perform the alternative scoring prescribed by step 7, six Edwards AFB projects competing for the fiscal year 2022 decentralized FSRM funding were evaluated using the decision model described in the previous chapter. Then, deterministic analysis prescribed by step 8 was performed using value scores for each of the projects. Deterministic analysis helps rank the projects and explain why the best-ranking project scored the highest. The resultant VFT-based rank order is compared to the ranking of these same projects according to current AFCEC business rules. Finally, the sensitivity analysis prescribed by step 9 is performed to examine how changes in assigned weights affect the ranking of the six evaluated projects.

4.1. Step 7: Alternative Scoring

Six projects were randomly selected from Edwards AFB fiscal year 2022 (FY 22) list of proposed decentralized FSRM projects. Descriptions of these projects are given in Table 10. Descriptions of the projects were copied verbatim from the NexGen IT project management software.

Table 10. Descriptions of Projects Used for VFT Analysis

PROJECT TITLE	PROJECT DESCRIPTION
RPR Hangar Door System Building 1820	East and west hangar doors are in need of a complete refurbishment, to include new drive motors, limit switches, door alarms, door seals, etc.
RPR Renovate Offices AFRC Building 5620 (Airman & Family Readiness Center)	Reconfigure interior space to create 3 hard wall offices, replace carpet, and replace exterior door with storefront style door in building 5620.
RPR Running Track Building 2200	Repair running track at the base gymnasium.
RPR Asphalt Pavement Warehouse Loading Area Building 3735	Repair asphalt pavement at the loading area for Environmental Management Warehouse.
RPR Renovate Chapel 2 Space B Building 6447	Replace windows, paint exterior/interior, install new HVAC VAV to allow separate temp control between rooms, and reconfigure interior wall to create hallway between rooms. Replace T-bar ceiling and light fixtures.
RPR Renovate Youth Center Building 5210	Renovate boys & girls restrooms, and redo interior finishes and floor coverings. Repair/upgrade building system components as needed.

NOTE: RPR stands for repair

The MDI, FCI, and QLI scores for the six projects are shown in Table 11. The FCI scores for the projects were determined using the Builder asset management system. An overall building condition score for each facility was used to score the projects. Table 12 shows facility types from Table 9 that were applied to each project for determining QLI scores. The MDI scores come from the fiscal year 2022 Air Force Comprehensive Asset Management Plan (AFCAMP) Facility Project Scoring Worksheet, which contains the latest set of Tactial along with CATCODE MDI scores for Edwards AFB. The single-dimensional value functions used to convert the scores into uniform units of value are shown in Table 13. Conversion of individual value scores into uniform units of value concludes step 7 of the VFT process. The next step in the process is to perform deterministic analysis.

Table 11. MDI, QLI, and FCI Scores of the Projects

PROJECT	MDI	QLI	FCI
RPR Hangar Door System Building 1820	92	3	75
RPR Renovate Offices AFRC Building 5620	60	2	75
RPR Running Track Building 2200	52	5	70
RPR Asphalt Pavement Warehouse Loading Area Building 3735	51	2	10
RPR Renovate Chapel 2 Space B Building 6447	48	4	50
RPR Renovate Youth Center Building 5210	12	5	75

Table 12. QLI Facility Types Applied to the Projects

PROJECT TITLE	FACILITY TYPE
RPR Hangar Door System Building 1820	Airfield Operations Facility
RPR Renovate Offices AFRC Building 5620	Brigade, Battalion, Company Headquarters
RPR Running Track Building 2200	Gymnasium
RPR Asphalt Pavement Warehouse Loading Area Building 3735	Warehouses
RPR Renovate Chapel 2 Space B Building 6447	Chapel
RPR Renovate Youth Center Building 5210	Child Development Center

Table 13. MDI, QLI, and FCI Scores Converted Into Units of Value

PROJECT	MDI VALUE SCORE	QLI VALUE SCORE	FCI VALUE SCORE
RPR Hangar Door System Building 1820	1	0.6	0.3
RPR Renovate Offices AFRC Building 5620	0.7	0.4	0.3
RPR Running Track Building 2200	0.6	1.0	0.3
RPR Asphalt Pavement Warehouse Loading Area Building 3735	0.6	0.4	0.9
RPR Renovate Chapel 2 Space B Building 6447	0.5	0.8	0.5
RPR Renovate Youth Center Building 5210	0.2	1.0	0.3

4.2. Step 8: Deterministic Analysis

Deterministic analysis was performed to evaluate results of the alternative scoring step. The analysis helps in ranking the alternatives and gaining an understanding of the factors affecting said ranking. This understanding is valuable for the decision maker, as it provides insight into level of impact each value and measure has on the final ranking. Table 14 shows the ranking of the projects and their overall value scores. The scores were derived by applying tier 1 value weights to each tier 1 value score and then added together. The project for the repair of Building 2200 received the highest overall score. Therefore, it contributes the most value to achieving the installation commander's fundamental objective.

Table 14. Final Value Scores and Ranking for the Projects

RANK	PROJECT	Support Mission Capability (0.260)	Support Quality Of Life On Base (0.475)	Ensure Functionality Of Facilities (0.265)	Final Score
1	RPR Running Track Building 2200	0.156	0.475	0.080	0.711
2	RPR Renovate Chapel 2 Space B Building 6447	0.130	0.380	0.133	0.643
3	RPR Hangar Door System Building 1820	0.260	0.285	0.080	0.625
4	RPR Renovate Youth Center Building 5210	0.052	0.475	0.080	0.607
5	RPR Asphalt Pavement Warehouse Loading Area Building 3735	0.156	0.190	0.239	0.585
6	RPR Renovate Offices AFRC Building 5620	0.182	0.190	0.080	0.452

The cumulative bar graph shown in Figure 12 can be used to gain insight into project ranking by displaying the amounts of value contributed by individual tier 1 values towards the final score for each project. The bar graph shows that the project for Running Track Building 2200 scored the highest. This building, which houses the gym, ranked the highest thanks to receiving a maximum QLI score of 5 and a fairly low FCI score of 70, which converted to a relatively high value score; additionally, its MDI score was one of the lowest.

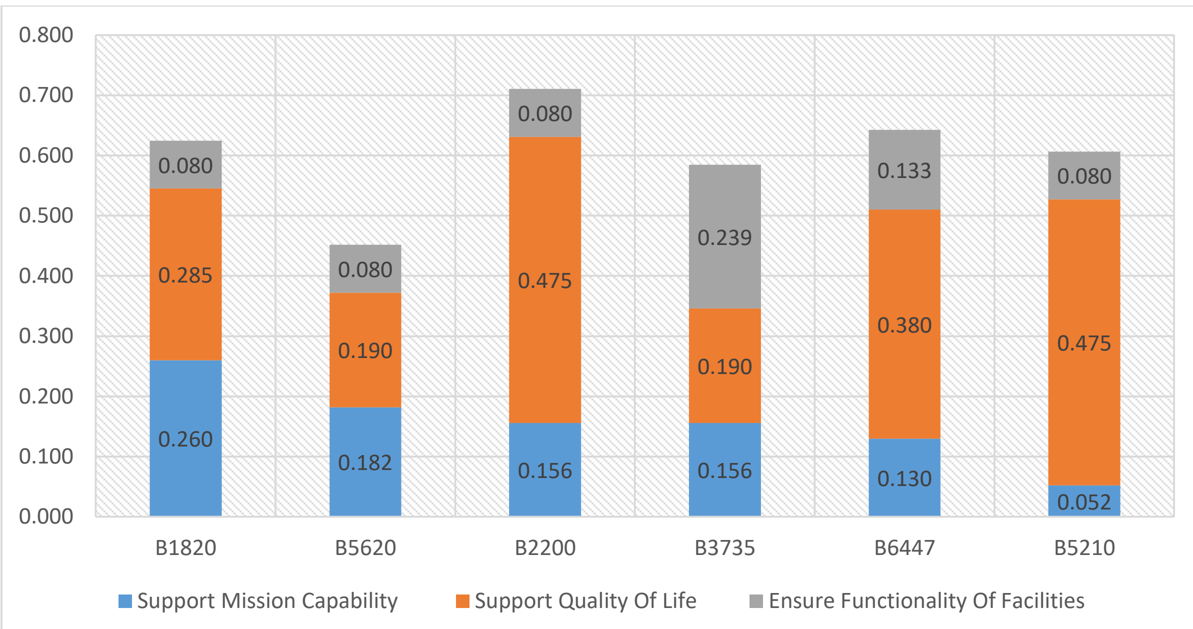

Figure 12. Contribution by Tier 1 Values to the Final Score for Each Project

The second highest scoring project was RPR Renovate Chapel 2 Space B Building 6447. The chapel received similar scores for the condition of the facility and its support for mission capability; it also received the third highest score for contribution to the quality of life. It is curious to see that the chapel received one of the lowest scores for its contribution to supporting mission capability yet still managed to rank second overall. This indicates that the VFT methodology manages to blunt the overwhelming effect of MDI on project ranking, which lets the quality of life and the facility condition contribute their fair share to the overall ranking of a project in line for funding.

This effect is evident when scores for the chapel are compared to scores for Hangar 1820, which is a flight line facility with an MDI of 92. This MDI is much higher than the MDI of 48 for the chapel. The AFCEC decision model would have scored the hangar higher at almost any FCI range and would not have accounted for the chapel's contribution to the quality of life on base. The VFT decision model, however, scored the chapel higher because it recognizes that the mission of the facility is not the only factor that dictates what decision-maker values. It also could not be said that the VFT-based decision model prioritizes quality of life over all other factors. The graph shows that building 5210, Youth Center, received a maximum QLI score of 5. However, it still scored fourth out of six projects due to its low MDI and FCI scores. In essence, Figure 12 offers a picture of a decision model that yields balanced results. In other words, this decision model does not rank order projects based exclusively on a single factor, but gives relevant priority to all the factors which are of concern for the decision maker.

Table 15 shows the ranking of the projects using the AFCEC decision support model, which makes it obvious why Edwards AFB CE leadership criticized the AFCEC approach. The highest ranked project is not the one in the worst condition, nor is it one that contributes the most to the quality of life of base personnel. The highest ranked project is for Hangar 1820 which has the highest MDI score. In fact, the table makes it obvious that there is a clear correlation between MDI scores and the rankings of the projects. Even the project for Building 3735 with an FCI of 10 and an MDI of 51 scored lower than the projects for buildings in better shape but with marginally higher MDIs. The chapel repair project was ranked second using the VFT model. However, the AFCEC model scores it second from the bottom due to its low MDI. Even though the Youth Center Building 5210 has the highest possible QLI score, it is scored low by both models due to its low MDI and high FCI scores. In summary, a comparison of the two rankings makes it obvious that the VFT-based model is better at aligning projects with the local mission as it takes into account not only the immediate importance of facilities to the Air Force mission but also their condition and contribution to the comfort of the base occupants.

Table 15. Ranking of the Projects According to the Fiscal Year 2022 AFCEC Business Rules

PROJECT	MISSION DEPENDENCY INDEX	FACILITY CONDITION INDEX	TECHNICAL SCORE	RANK
RPR Hangar Door System Building 1820	92	75	5465	1
RPR Renovate Offices AFRC Building 5620	60	75	3089	2
RPR Running Track Building 2200	52	70	2590	3
RPR Asphalt Pavement Warehouse Loading Area Building 3735	51	10	2540	4
RPR Renovate Chapel 2 Space B Building 6447	48	50	1296	5
RPR Renovate Youth Center Building 5210	12	5	720	6

4.3. Step 9: Sensitivity Analysis

Sensitivity analysis was used to scrutinize how variations in the weights of the values affect the ranking of the projects being evaluated. Several final scores for each project are calculated for that range of weights. Points representing the final scores of each project are then plotted on a graph and fitted with a trend line. The final graph helps to see how project ranking changes depending on variation in a given value's weight.

Sensitivity analysis was performed on the tier 1 values, which represent the overarching values of the decision-maker. Therefore, stakeholders would primarily want to change weights assigned to tier 1 values if there is a disagreement between stakeholders on the final ranking of the projects. An example of such a situation would be if a new installation commander decides to, for example, emphasize the functionality of facilities over mission capability and quality of life on base.

Values of Support Mission Capability, Support Quality of Life, and Ensure Functionality of Facilities constitute tier 1 of the value hierarchy. Their global weights are changed to perform sensitivity analysis. In fact, their local weights and global weights are the same in the case of this value model because they all fall under the same fundamental objective in the hierarchy. Moreover, there is no reason to perform sensitivity analysis for the measures since there is only one measure for each of the tier 1 values.

Figure 13 shows the results of the sensitivity analysis performed on the value of Support Mission Capability. For the initial analysis, the weight of the value is changed gradually from 0 to 1 while keeping the weights of the other values in their original proportionality to each other. The initial weight of the Support Mission Capability tier 1 value is 0.260. Visual assessment of the graph indicates that the final scores of the projects for buildings 2200, 5210, and 6447 are inversely proportional, while the final scores of the projects for buildings 1820, 5620, and to a lesser extent, 3735 are directly proportional to the increase in weight of value Support Mission Capability. Note that the initial weight of the value sits in the major trend line intersection segment. Therefore, decision-makers must be mindful that slight changes to the weight of this value can significantly alter the ranking of the projects.

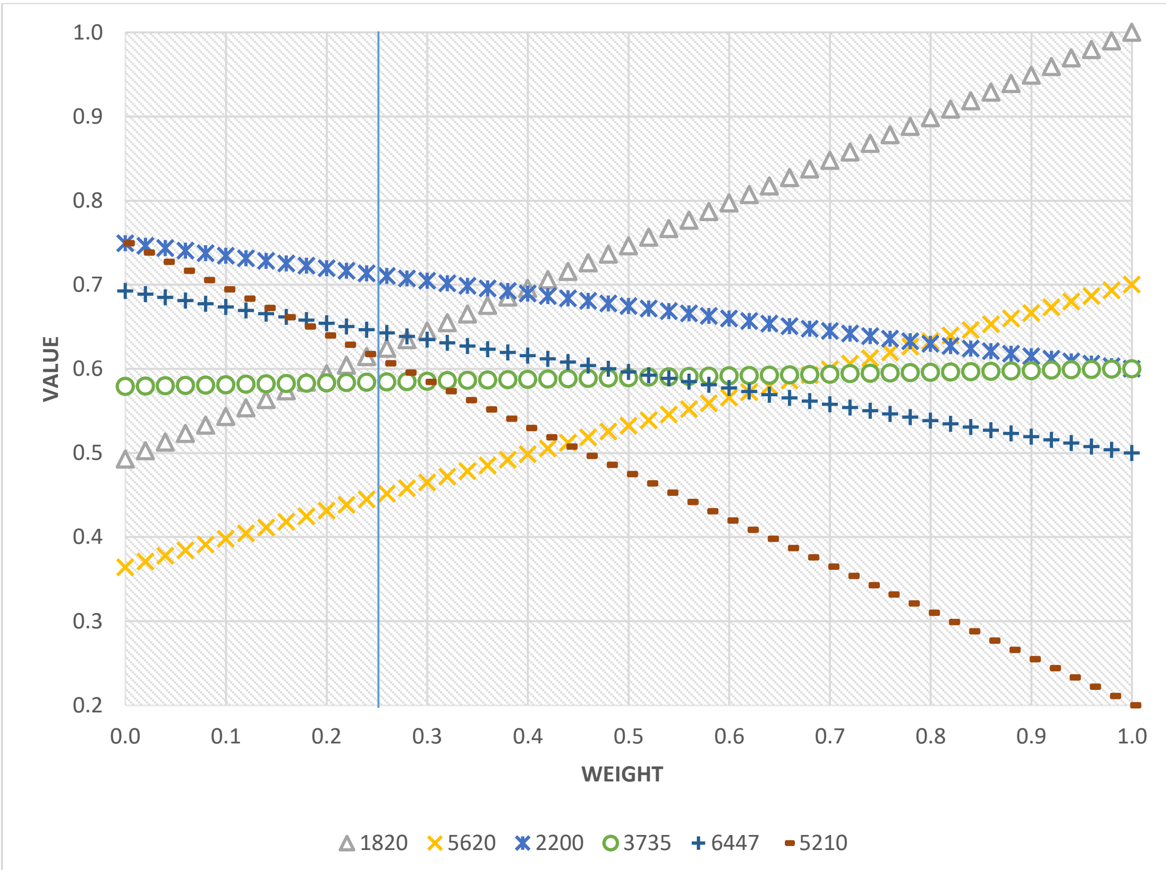

Figure 13. Sensitivity Analysis of Support Mission Capability Tier 1 Value

At the initial weight of 0.260, the RPR Running Track Building 2200 project is the highest ranked alternative. However, as the weight of Support Mission Capability increases, the project for Building 1820 becomes the most preferred alternative at a weight of about 0.40. Since the project requires the repair of the hangar door, it received a value score of 1 for a measure of MDI, which is a maximum score, because it has an MDI of 92 out of 100. The project did not get the highest scores for the other two measures. It scored 0.6 for QLI and 0.3 for FCI. As the proportion of MDI in the final score increases with the increase in weight, the project gains in ranking, eventually ranking first, up from third at the initial weight.

Another dramatic change occurs in the ranking of the project for Building 5210, which requires the renovation of the youth center. It scored low because Building 5210 has an assigned MDI score of only 12, which represents a value score of 0.2 for the MDI measure. The project also received value scores of 1 for QLI and 0.3 for FCI. The dramatic negative gradient of the trend line for this project results in a significant change in its ranking. After a 0.2 increase in the weight of mission support from its original value of 0.260, the project drops to the last spot in the ranking. The projects for buildings 5620, 6447, and 2200 are also fairly susceptible to changes in weight of Mission Support but not to the extent of the projects for buildings 5210 and 1820. The slopes for their trend lines are not as dramatic because they have a relatively even distribution of scores across the three measures. Their MDI scores are also average because all three represent support facilities and are on the flight line. Due to these reasons, a change in weight of the Support Mission Capability tier 1 value does not result in extreme changes in their rankings. The project for Building 3735 is the most resilient to changes in weight of this tier 1 value. Its final value score stays around 0.60 mark throughout the analysis due to its low FCI score of 10, which translates to a high value score of 0.90. This score balances out changes in the weight of mission support to keep building 3735 ranked mostly fourth throughout the analysis.

Figure 14 shows the results of further sensitivity analysis performed on the value of Support Mission Capability. This time, the weight of the value is held constant at its original magnitude of 0.260, while the weights of other two values are changed. As the weight of

Support Quality of Life is gradually changed from 0 to 0.740, the weight of Ensure Functionality of Facilities changes proportionately and in reverse from 0.740 to 0. The vertical line shown in Figure 14 is placed at the weight of 0.475, which is the original weight for Support Quality of Life. The same point is equivalent to the original weight of Ensure Functionallity of Facilities at 0.265. The figure shows how the projects for buildings 2200 and 5210 rise in rankings as more emphasis is placed on the quality of life versus the functionality of facilities. The opposite is true for the ranking of the project for building 3735. The ranking of the project for the repair of building 5620 stays relativy stable throughout the analysis.

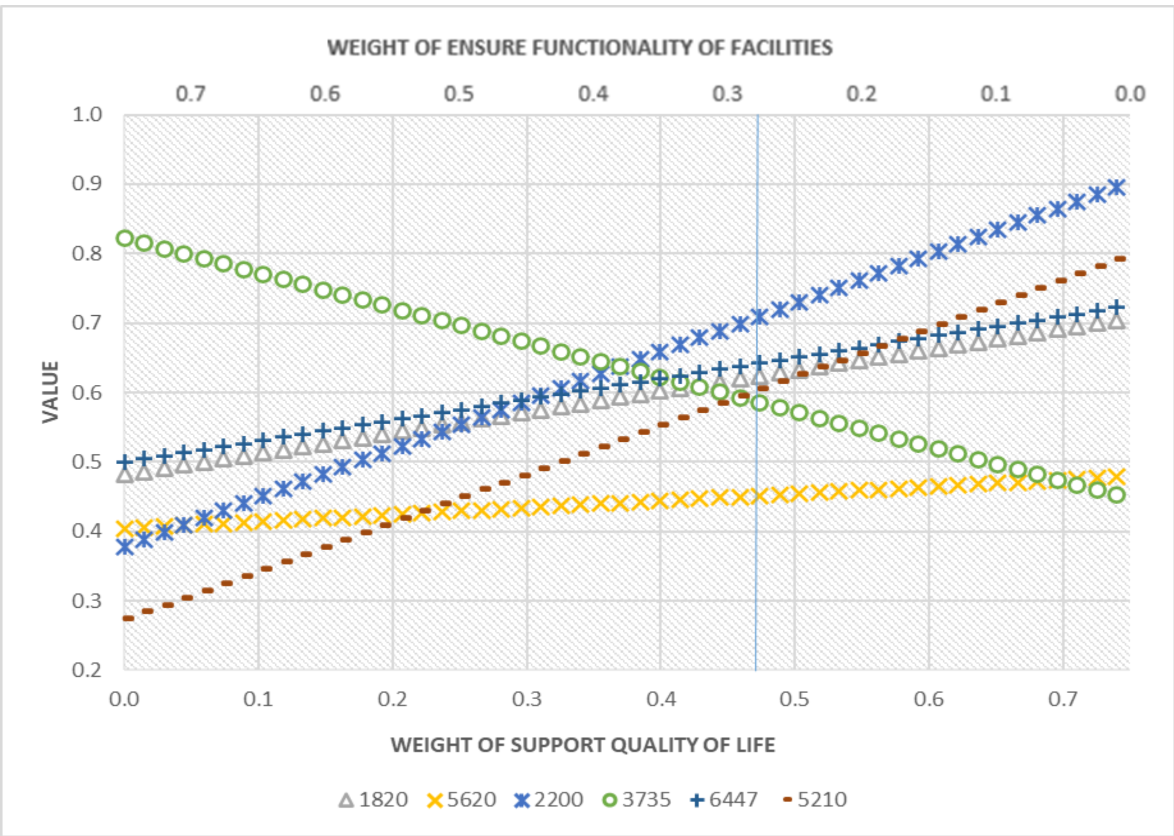

Figure 14. Sensitivity Analysis with Support Mission Capability Tier 1 Value Held Constant

The result of sensitivity analysis on the value of Support Quality of Life on Base, which had an initial weight of 0.475, is shown as Figure 15. As the figure shows, the most drastic slopes can be attributed to the projects for buildings 5210, 2200, 3735, and 6447. The most dramatic positive slope is displayed by the Building 5210 youth center project. The youth center received low scores for MDI and FCI but a maximum score for QLI. This combination of a single high score and two low scores is responsible for its rapid rise in response to an increase in the weight of Support Quality of Life. A similar trend is apparent in scores for the Building 2200 project, which also received a maximum score of 1 for QLI. The scores for buildings 2200 and 5210 eventually converge at a weight of 1; however, throughout most of the analysis, the project for Building 2200 ranks first. This is due to a higher MDI score of 52 for the gym, compared to the MDI score of 12 for the youth center. Since their FCI scores are similar though, the FCI is not a significant differentiator between the two projects. The project for Building 6447 also increases in value with the increase in weight of value Quality of Life on Base. The chapel was determined to have a significant contribution to the quality of life and therefore was assigned a score of 4 for the measure of QLI. Past a weight of 0.56, the project for the chapel ranks third behind the projects for buildings 2200 and 5210. However, at a QLI weight of zero, it starts from a higher position relative to those two projects due to its lower FCI score.

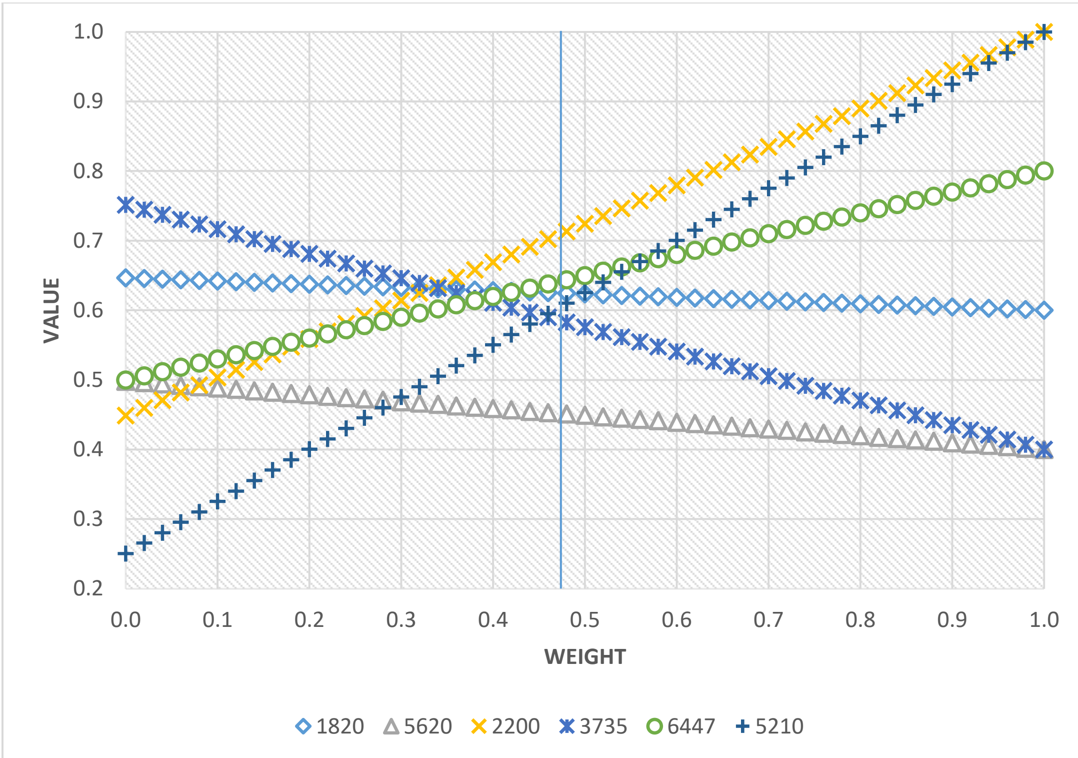

Figure 15. Sensitivity Analysis of Support Quality of Life on Base Tier 1 Value

The project for Building 3735 is inversely proportional to increases in the weight of Support Quality of Life. The project for this building received a low QLI score of 0.4, along with scores of 0.6 for MDI and 0.9 for FCI. As the portion that is attributable to QLI in the final score increases with the increase in its weight, the total score for Building 3735 decreases due to its low QLI score, thus presenting a dramatic decrease in ranking. Value scores for buildings 5620 and 1820 show resilience to changes in the weight of quality of life. This is due to a combination of two factors: an even distribution of scores across all three measures and mid-range QLI scores. Despite the resilience of the final value scores of the project for Building 5620, it ranks last past a weight of 0.30 for Support Quality of Life. Although the scores the project received across the measures are close to each other, they are still low compared to other projects.

Figure 16 shows the results of additional sensitivity analysis performed on the value of Support Quality of Life on Base. For this analysis, the weight of the value is held constant at its original weight of 0.475, while the weights of other two values are changed. As the weight of Support Mission Capability is gradually changed from 0 to 0.525, the weight of Ensure Functionality of Facilities changes proportionately and in reverse from 0.525 to 0. The vertical line shown in Figure 16 is placed at the weight of 0.260, which is the original weight for Support Mission Capability. The same point is equivalent to the original weight of Ensure Functionallity of Facilities at 0.265. The figure shows how the projects for buildings 2200, 1820, and 5620 rise in rankings as more emphasis is placed on the mission capability versus the functionality of facilities. The opposite is true for the ranking of the project for building 3735. Ranking of the projects for the repair of buildings 6447 and 5210 stay relativy stable throughout the analysis.

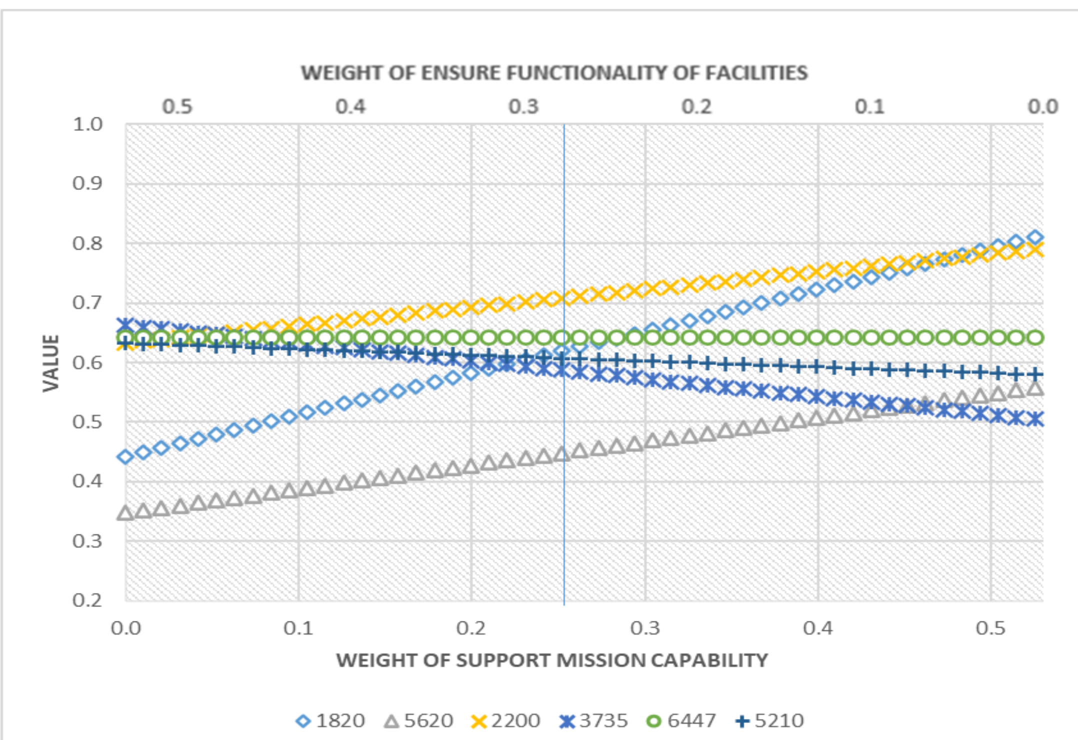

Figure 16. Sensitivity Analysis of Support Quality of Life on Base Tier 1 Value Held Constant

The result of performing sensitivity analysis on Ensure Functionality of Facilities, which had an initial weight of 0.265, is shown in Figure 17. The most dramatic positive slope is displayed by the project for Building 3735, which is a warehouse. It received value scores of 0.6 for MDI and 0.4 for QLI, but a score of 0.9 for FCI. Building 3735 received a high Ensure Functionality of Facilities value score due to its low FCI rating of 10, the lowest among all the projects. This indicates that Building 3735 is in bad shape and an increase in weight of value Ensure Functionality of Facilities beyond 0.40 results in the project being the highest ranked, compared to its initial 5th place ranking. The project for Building 2200 is ranked first at the initial weight, but drops to ranking third past a weight of about 0.43 due to its above-average condition index of 70. Its dramatic negative slope can be attributed to the project's relatively high scores for values of mission dependency and quality of life.

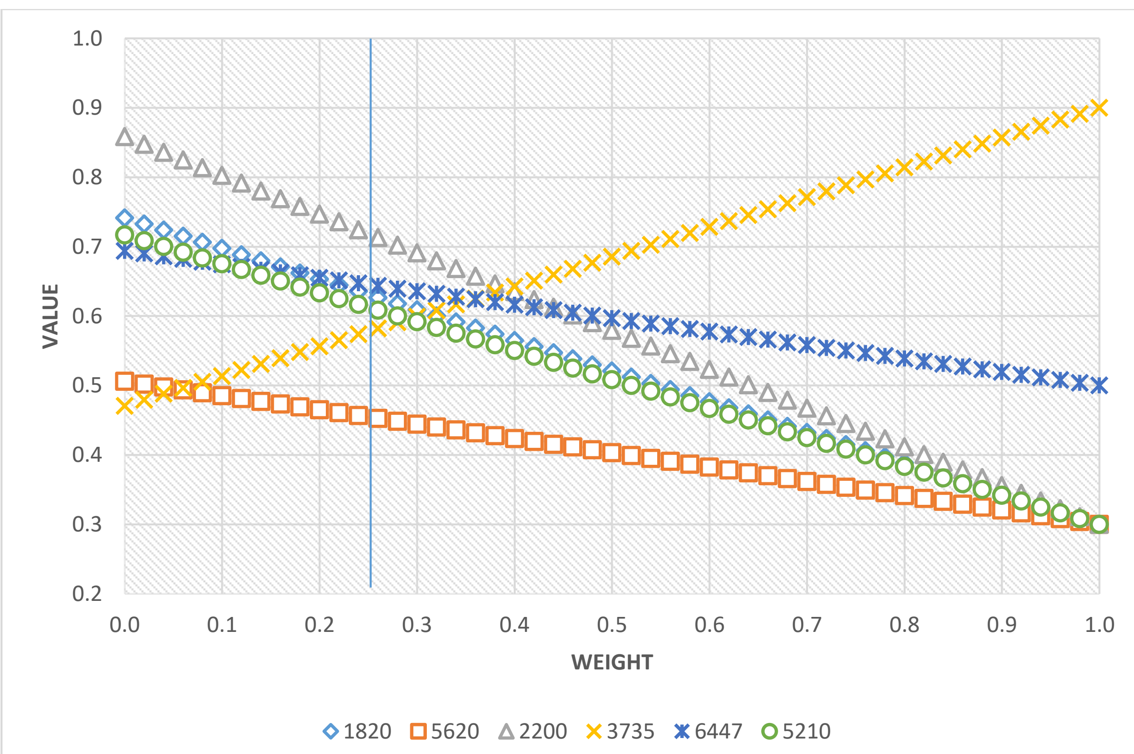

Figure 17. Sensitivity Analysis of Ensure Functionality of Facilities Tier 1 Value

The trend lines of the projects for buildings 5210 and 1820 are mostly aligned. Although the scores these projects received for measures of MDI and QLI are quite different, the sums of these two values are similar once the weights are applied. Their negative slopes can be attributed to their low FCI scores; they both drop in ranking as the share of the Ensure Functionality of Facilities value in the final score increases with its increasing weight. The project for Building 5620 consistently ranks last in the analysis due to the fact that the building does not significantly contribute to the quality of life, as reflected by its QLI score of 2. Additionally, it does not greatly contribute to mission support, with an MDI score of 60. Furthermore, the building is in relatively good shape, with an FCI score of 70.

Finally, Figure 18 shows the results of sensitivity analysis performed on the value of Ensure Functionality of Facilities, where the weight of the value is held constant at its original magnitude of 0.265, while the weights of other two values are changed. As the weight of Support Mission Capability is gradually changed from 0 to 0.735, the weight of Support Quality of Life changes proportionately and in reverse from 0.735 to 0. The vertical line shown in Figure 18 is placed at the weight of 0.260, which is the original weight for Support Mission Capability. The same point is equivalent to the original weight of Support Quality of Life at 0.475. The figure shows how the projects for buildings 1820, 3735, and 5620 rise in rankings as more emphasis is placed on the mission capability versus the quality of life. The opposite is true for the rankings of the projects for buildings 2200, 6447, and 5210.

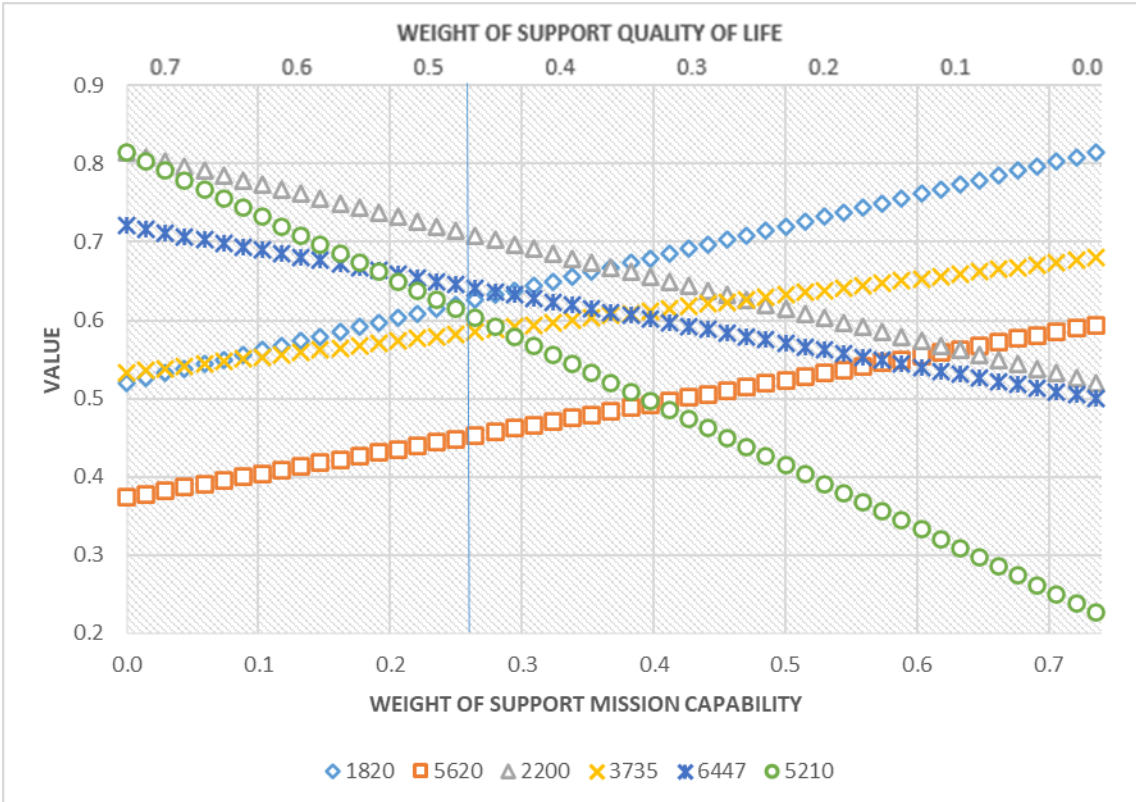

Figure 18. Sensitivity Analysis of Ensure Functionality of Facilities Tier 1 Value Held Constant

4.4. Summary

Chapter IV covered steps 7 through 9 of the VFT process. Deterministic analysis was performed on six randomly selected fiscal year 2022 projects submitted for decentralized FSRM funding at Edwards AFB. The results of the analysis were used to rank the projects from most desirable, from the perspective of their value contribution to the decision-maker's mission, to the list desirable. The project for Building 2200 ranked the highest and the project for Building 5620 ranked the lowest. The measure of QLI is the biggest contributor to the final value score for the Building 2200 project, 67% of the total score, due to its very high QLI score and the high weight of the Quality of Life tier 1 value. The project for Building 5620 scores the lowest due to it having a mid-range MDI of 60, relatively low QLI of 2, and the building being in comparatively good shape with an FCI of 75.

The ranking of the projects under deterministic analysis was compared to a ranking of the same projects under current AFCEC business rules. The comparison showed that the VFT-based ranking results in a balanced portfolio of projects compared to AFCEC methodology. The balance is evident when analyzing the distribution of MDI scores in project rankings. While the AFCEC model overwhelmingly emphasizes MDI scores when ranking the projects, as can be seen in Table 16, the VFT-based model does not emphasize one measure over the two others, as evident in Tables 13 and 14.

Sensitivity analysis was performed on all three tier 1 values. Sensitivity analysis shows changes in the ranking of the projects with changes in tier 1 value weights. The analysis showed that projects with larger differences between individual value scores exhibit the most drastic trend line slopes. In other words, projects that rank very well in only one value are much more sensitive to changes in weight of that one value compared to projects that rank more evenly across all the values.

Chapter V. Findings and Conclusions

Chapter V summarizes the findings and draws conclusions regarding the application of the VFT methodology to civil engineering project selection. The first section summarizes responses to questions that guided this research and were first formulated in Chapter I. The next section describes the effect the developed decision support model is expected to have on FSRM project selection at Edwards AFB. Value model strengths and weaknesses are addressed in the subsequent section. Finally, recommendations for future research are presented.

5.1. Investigative Questions Answered

This section discusses the insight gained by answering the three investigative questions that guided this research. The first investigative question was: *Why does the current AFCEC decision support framework scores facilities occupied by base Facility Support Services lower than facilities located on the flight line?* Through the literature review, it was discovered that a significantly higher MDI is assigned to buildings on the flightline versus all others. This discrepancy in MDI scores, in conjunction with the disproportionate emphasis AFCEC places on MDI when scoring projects, is a major factor in non-flightline facilities being passed over for funding. Chapter II also discusses the structural defects associated with the way MDI was derived and applied, as was the case with issues that arose when the Air Force adopted MDI by merely relating Navy's facility MDI scores to the Air Force facility CATCODES. Despite the issues undermining the use of MDI, the challenges are not insurmountable and can be fixed. The Air Force has been working on fixing the problems by recently rolling out the Air Force MDI re-baselining effort which introduced a tactical MDI. If derived locally and vigorously, MDI is a powerful tool for evaluating projects based on their contribution to the Air Force mission.

MDI is not the only culprit behind the low funding rate of non-flightline facilities. As was discovered through discussions with panel members, the AFCEC decision support model also neglects to take into consideration the quality of life on base. It was discussed that quality of life is one of the values derived from Air Force publications that the installation commander needs to uphold. It was agreed by panel members that quality of life is not necessarily synonymous with facility condition index but rather a function of the purpose of a facility. Therefore, the VFT-based decision support model needed to account for both of these values independently. The Air Force took a step toward tackling the issue of imbalanced facilities funding by establishing decentralized funds via the Air Force Guidance Memorandum to AFI 32-1032. Decentralized funds establish local authority for distributing funds for projects with programmed amounts within certain limits. However, this memo did not prescribe a methodology to use for deciding which projects to fund. This research addressed this shortcoming by developing a VFT-based decision support mechanism that would resolve all the issues that affected the AFCEC model.

The second investigative question was: *What would the resultant decision support framework be for FSRM projects if Value Focused Thinking methodology was adopted by Edwards AFB?* The development of the VFT-based decision support framework, described in Chapter III, revealed that there are three principles or values that panel members derived from the Air Force publications describing CE's mission statement. These three values and their associated weights are Support Mission Capability (0.26), Ensure Functionality of Facilities (0.265), and Support Quality of Life on Base (0.475). The respective measures for these value were the Mission Dependency Index, Facility Condition Index, and Quality of Life Index.

Third investigative question was: *Which projects should 412 CEG pursue to fulfill its mission?* Chapter IV applied the VFT-based decision support model to the ranking of six randomly selected projects competing for FY22 decentralized FSRM funding. When comparing this ranking to the ranking obtained from the AFCEC model, the average difference in raking was 2.33, which is significant since only six projects were evaluated. Additionally, the comparison showed that the VFT-based ranking results in a balanced portfolio of projects compared to the AFCEC model.

Finally, the overarching question this research set out to answer was: *How can a decision support framework be created that ranks FSRM projects for funding in facility and infrastructure maintenance organizations and results in a balanced portfolio of projects?* Using the VFT methodology, this research was successful in developing a transparent, repeatable, and defendable decision support mechanism based on decision-maker's values for the base leadership to score and rank projects in line for funding. The model was tested by applying it to the ranking of actual projects, and the results were successfully analyzed. Therefore, the answer to the overarching question is, the VFT process yields a decision support framework that ranks FSRM projects for funding at facility and infrastructure maintenance organizations based on decision-maker's values, which results in a balanced portfolio of projects.

5.2. Impact

The impact of this research is that a transparent, repeatable, and defendable decision support mechanism based on a tested and previously successfully applied methodology was created for the base to score and rank projects for local funding. Projects selected for funding using the VFT decision support model will be chosen based on their contribution to reaching goals established by the decision-maker. This focused effort to satisfy *all* values outlined by the mission statement will help implement projects that increase the quality of life on base without adversely affecting mission readiness, functionality, and the safety of the facilities.

5.3. Value Model Strengths

The model can be characterized by its high operability, meaning that the model values can easily be understood by a layperson. This is especially important in public organizations where organizational leadership decisions are subject to questioning by the public. Another advantage of this hierarchy is its small size, which makes the decision support framework workable. It is not too big and too cumbersome for practical use. The MDI, FCI, and QLI measures are all immediately available for a programmer to plug into the value equation, thus allowing a single programmer to evaluate and sort many different projects in a relatively short amount of time. Moreover, this model can be characterized as having a "gold standard" foundation. This means that the hierarchy is in accordance with the Air Force publications which guide activities of base CE. It makes the model defendable to outside examination.

5.4. Value Model Weaknesses

One weakness of this model is an assumption that the constructed QLI measure, which the panel members agreed on using in the model, would be acceptable to the installation commander as a true reflection of value attainment. The intent of introducing this value to the hierarchy was to raise the quality of life for both the civilian and military populace on base. The panel reasoned that the measure truly relates to the base populace's emotional perception of the importance of a facility to quality of life. Therefore, ideally, scores for various facilities have to come from a direct survey of the entire base populace. However, it was not possible to survey the entire base for this study due to time and resource constraints. Besides, it is doubtful that permission to conduct such a survey would have been received. The inability to survey the base populace directly may result in disagreement of some members of the base community with the final ranking of projects by the model.

5.5. Conclusion

This research has produced a decision support model that is transparent, repeatable, and defendable. It was derived using a proven decision support methodology. The model was developed by CE's most experienced personnel. It evaluates projects based on how well they align with decision-maker's values and therefore helps focus the effort on achieving installation commander's mission. Therefore, it is recommended that this tool should be adopted by the 412th CEG to score and rank projects for decentralized FSRM funding that is allocated by the installation commander.

5.6. Recommendations for Future Work

Future research should review the MDI, FCI, and QLI measures detailed in this study. Future studies may determine or develop measures that are better at gauging the extent of value attainment compared to the current ones. This is particularly relevant to the constructed QLI measure. Moreover, it is recommended that a base-wide survey of military and civilian personnel be conducted. The survey should ask the entire base populous to assign a score to base facilities based on their contribution to the quality of life. Such a survey would lend validity to the QLI measure if no alternative to this measure is found. If another panel is assembled for future research, then it is recommended that membership of the panel be expanded to include appropriate Air Force Civil Engineer Center (AFCEC) and Major Command (MAJCOM) subject matter experts, representatives of the all the base missions, organizations, and tenants. Expanding the panel membership to AFCEC, MAJCOM, and base missions, organizations, and tenants would encourage validity and the Air Force-wide adoption. A future study might also consider further breaking down the values. Further decomposition of values might improve the accuracy of project scoring. However, future research should also make an effort to avoid making scoring projects too cumbersome and complicated in pursuit of greater accuracy. Research into automating the entire scoring and ranking process might be helpful in overcoming the excessive effort that greater model accuracy might demand.

5.7. Summary

The final chapter presented answers to the questions formulated for this research. It discussed the expected impact of the application of the resultant VFT-based decision support model on project selection for execution by the 412th CEG. It also discussed the model's strengths and weaknesses. Recommendations for future work were presented in this chapter along with conclusions.

Appendix A: Air Force Guidance Memorandum to AFI 32-1032

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS UNITED STATES AIR FORCE
WASHINGTON DC

AFI32-1032_AFGM2018-01

23 May 2018

MEMORANDUM FOR DISTRIBUTION C
MAJCOMs/FOAs/DRUs

FROM: HQ USAF/A4
1030 Air Force Pentagon
Washington, DC 20330-1030

SUBJECT: Air Force Guidance Memorandum to AFI 32-1032, Planning and Programming Appropriated Fund Maintenance, Repair, and Construction Projects

3.2.1. In order to support the Chief of Staff of the Air Force's efforts to reinvigorate squadrons and develop leaders as well as decrease the effort required by civil engineers at every organizational level, wing's will assume greater responsibility to fund relatively small dollar repair projects beginning with the Fiscal Year 2020 AFCAMP. Installations competing for centralized facility repair project funding via the AFCAMP will not submit projects less than the following thresholds to enable and allow for localized prioritization:

Sustainment repair projects - $2 million

Restoration & Modernization repair projects - $1 million

For projects that include a combination of repair work classes, the threshold applies to the work classification comprising the majority of the requirement.

This policy is about trusting commanders to make good decisions with limited resources. AFIMSC will establish a funds allocation methodology that follows the spirit and intent of this policy to reduce project funding approval workload. AFIMSC will develop decision support tools (Performance indicators) to measure allocation and execution effectiveness. The allocation methodology will be reviewed annually based on the established performance indicators.

(T-1)

Appendix B: 412th CEG Panel Guidance and Questions

1- INTENT OF THE THESIS:

Discussions with the 412th CE team revealed that there was general dissatisfaction with the current AFCEC method of choosing FSRM projects for funding. It was stated that the current method prioritizes flightline buildings to the detriment of buildings supporting local missions.

This thesis intends to devise an alternative decision support tool to be used to choose which FSRM projects to fund. This tool is intended to be used for picking FSRM projects that fall under new funding thresholds described on the 23 May 2018 HQ USAF/A4 issued memorandum. The memorandum intends such projects to be locally prioritized making them ideal for use with a new locally devised decision support tool. It is an opportunity for local CE to prioritize projects as they see necessary. Applying a proven decision support methodology to come up with such a decision support tool ensures that the tool is transparent, repeatable, and defendable.

The author picked Value Focused Thinking (VFT) methodology to help create a decision support tool for this purpose. This example is distributed among the members of the 412th CEG panel tasked with developing said decision support tool.

First, the example on the following pages will explain VFT. Then, it will ask each panel member to brainstorm values to be input into the decision support tool.

Once all the proposed values from all members of the panel are received, a meeting will be arranged to discuss everyone's responses and to agree on a common value hierarchy.

2- WHAT IS VALUE FOCUSED THINKING?

Traditionally decisions were made using Alternative Focused Thinking (AFT). This methodology evaluated alternative choices presented to a decision-maker. These choices did not necessarily align with the decision-maker's values, thus the results of performing a portfolio of such projects did not lead to the best possible outcome for an organization. Value Focused Thinking (VFT) remedies this shortfall of AFT by evaluating projects on basis of how good each project is at helping an organization reach its goals/mission statement.

3- BUYING A TRUCK EXAMPLE

This section explains VFT using a simple example of devising a VFT-based decision support model for buying a truck. There are ten steps in this process. Figure 1 shows all 10 steps involved in the process.

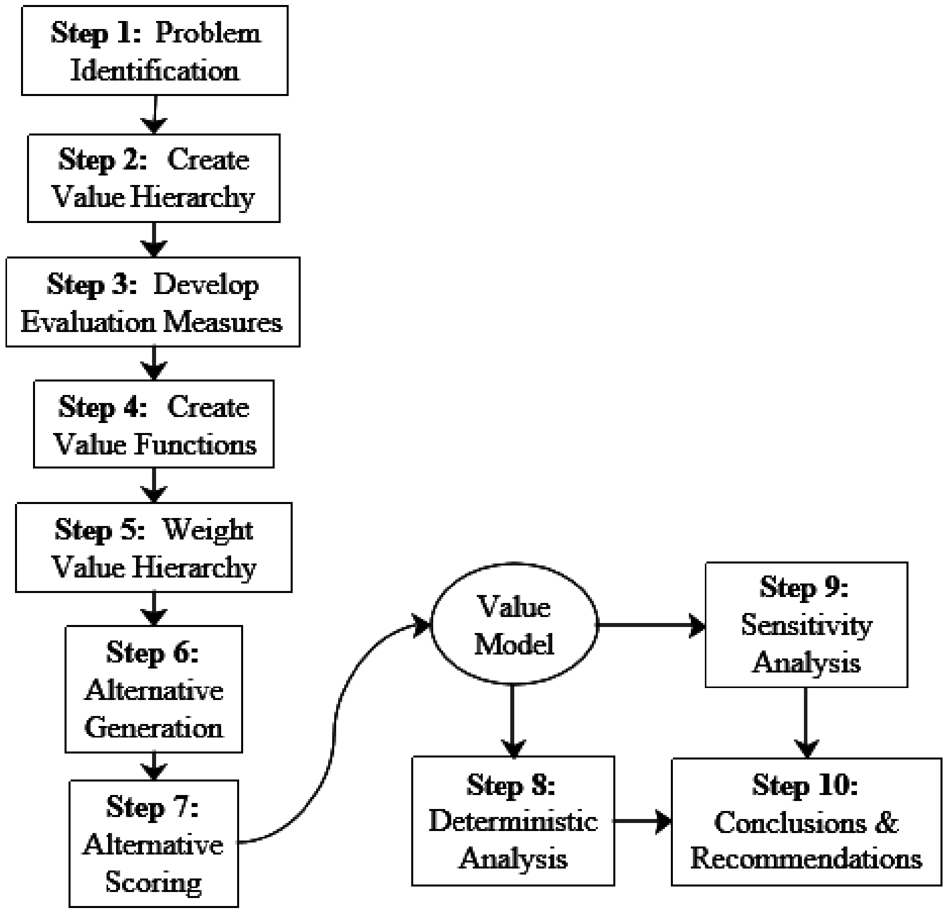

Figure 1. Step in the VFT process (Shoviak, 2001, p.63.)

Step 1 – Problem Identification:

Problem is that the decision-maker has a choice to make. He wants to buy a truck but is not sure which one to buy. Therefore, the decision-maker turns to VFT to put together a decision support tool he will use to evaluate the alternatives. This tool will help him make it clear what he is looking for in a truck, i.e. what he values in a potential truck.

Step 2 – Create Value Hierarchy:

He starts with a goal and then makes a list of values, which describe the attributes of his future truck. He puts those values/attributes into a hierarchy as shown in Figure 2. The major (tier 1) attributes flow from the goal and minor (tier 2) attributes flow from major attributes. Each tier breaks down or further defines/clarifies the values of the decision-maker.

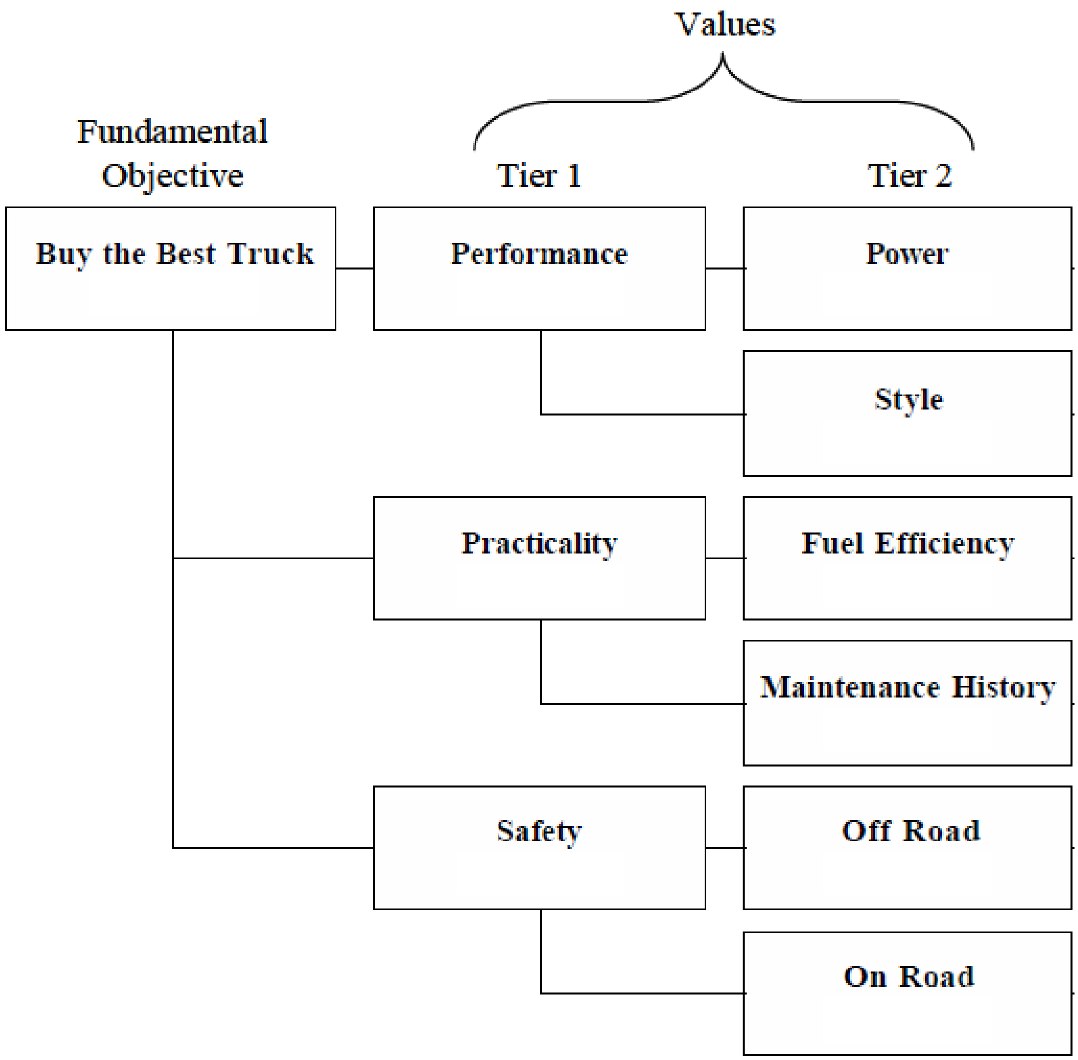

Figure 2. Buy the Best Truck Example Value Hierarchy (Jurk, 2002)

Step 3 – Develop Evaluation Measures:

When a value cannot be broken down further into sub-values then we have to determine what measures to use to evaluate the values. The last/bottom tier of any branch contains these measures. Measures are used to indicate the degree of attainment of the value above. There could be more than one measure per value. Figure 3 shows measures assigned to the value hierarchy in Figure 2.

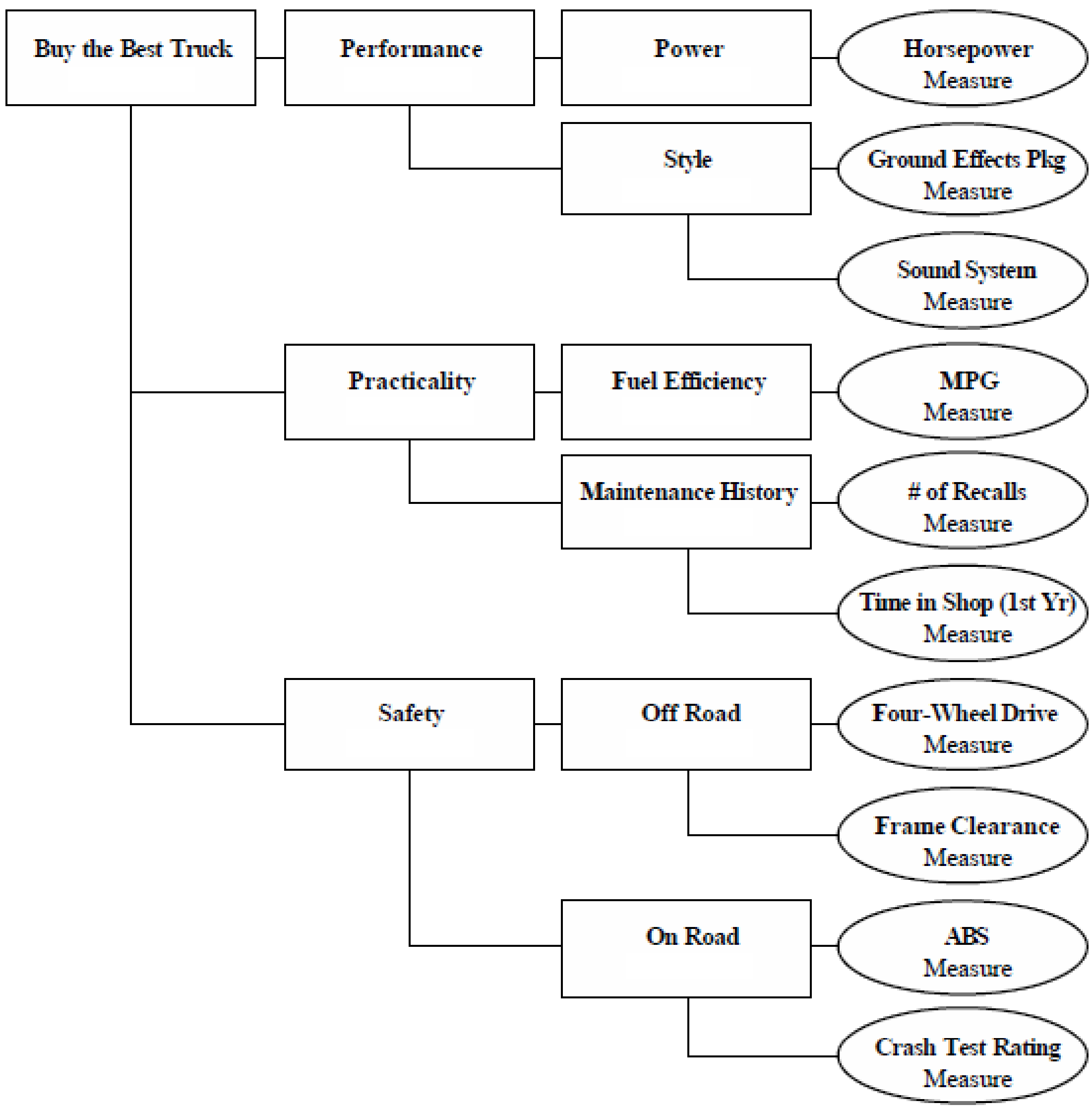

Figure 3. Buy the Best Truck Value Hierarchy with Measures (Jurk, 2002)

Step 4 – Create Value Functions:

This example will skip Step 4. Step 4 will be discussed in-group setting by panel members once brainstormed values are collected.

Step 5 – Weight the Value Hierarchy:

In this step, all the values and measures need to be assigned weights. Weights indicate the degree of importance of the measure or a value in the hierarchy for a decision-maker. The weights of each tier have to sum to 1, see Figure 4. You can think of this as a percentage of importance the decision-maker assigns each value.

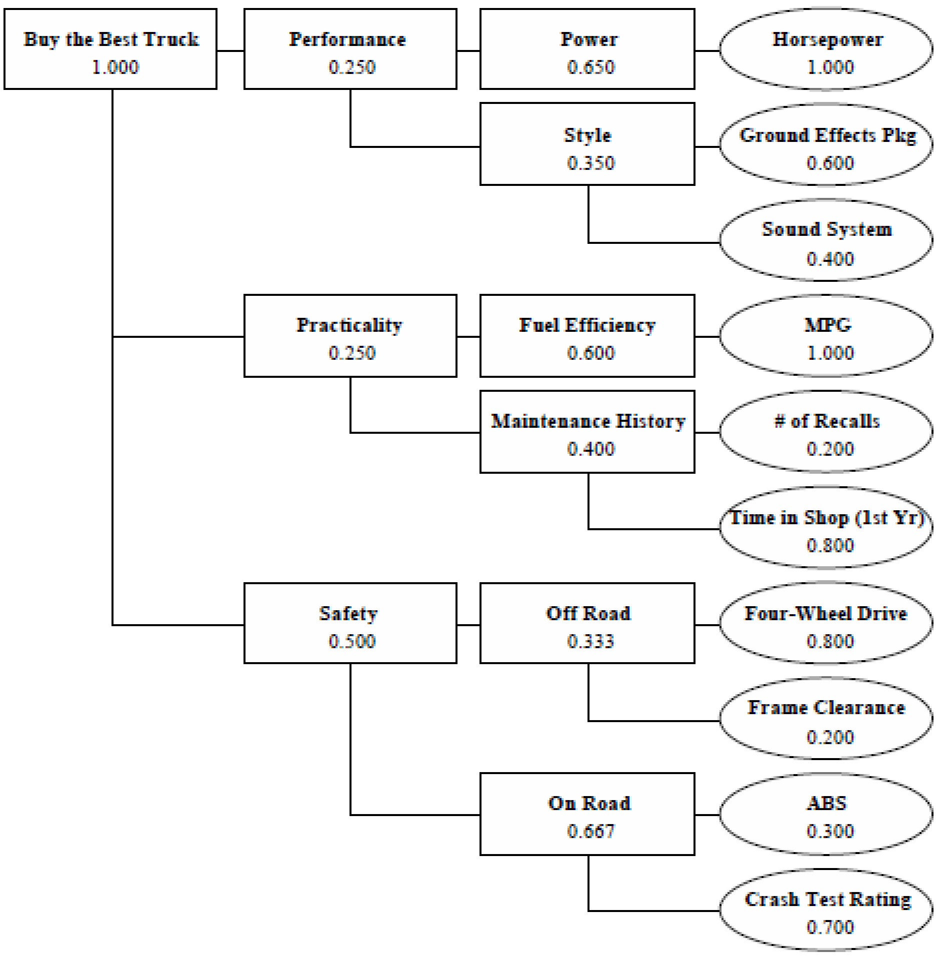

Figure 4. Buy the Best Truck Value Hierarchy with Local Weights (Jurk, 2002)

Step 6-10

The aim of this research is to devise a decision support model based on VFT. Steps 1-5 accomplish that goal. Steps 6-10 deals with the actual alternative generation, scoring, and analysis of results, i.e. those steps deal with the actual implementation of the model. Therefore, those steps are beyond the scope of this research.

4- PRE-MEETING BRAINSTORMING QUESTIONS

Please brainstorm values to be used in the decision support hierarchy for FSRM projects. Brainstorm values only. Measures, value functions, and weights will be determined at the meeting. There are no right or wrong values. <u>You</u> are the subject matter expert. The research is interested in <u>your</u> opinion. Please email the values to the author.

Once the author receives the values from each member of the panel he will put together a draft, straw-man hierarchy, and schedule a meeting. At the meeting panel members will discuss this strawman hierarchy and revise it if necessary. Next, at the same meeting panel members will brainstorm measures for values in the hierarchy, create value functions and finally assign weights to values and measures.

Appendix C: Documentation of Meetings with 412th CEG Team

Meeting Dates: Intermittently between 13 - 19 October 2020

Location: Civil Engineer Buildings at Edwards AFB

412th CEG Members That Participated in the Discussions:

- Member #1
- Member #2
- Member #3
- Member #4
- Member #5
- Member #6
- Member #7

Purpose of the Meetings:

1. Explain VFT methodology to all the panel members using a *Buy the Best Truck* example.
2. Have panel members determine which the Air Force publicans should be used as guidance in determining values.
3. Brainstorm values and measures.
4. Organize those into a hierarchy.
5. Assign weights to values.
6. Create value functions for measures.

Meeting Highlights:

1. Bayram Kurbanov met with each of the panel members and used the "Buy the Best Truck" example to introduce them to the VFT methodology.

2. Explained what "Gold Standard" means and its implications for having a transparent and defensible hierarchy.

3. Discussed AFI 32-1032, AFI 32-1001, and AF Policy Directive 32-10 and solicited each member's opinion on governing principles/values that should be derived from those publications.

    a. All members independently stated that tier 1 values have to consist of mission support, functionality, and quality of life.

4. Author asked if governing tier 1 values should be broken down into sub-values/tier 2 values.

    a. After brainstorming and discussion of other panel members' responses every panel member agreed that there was no need for a further breakdown of tier 1 values.

5. Author asked which measures should be assigned to tier 1 values.

    a. All panel members agreed to use MDI and FCI measures. No ready measure was available for quality of life value. One of the panel members suggested the use of UFC 4-020-01 to identify typical facilities on base and assign each of those a score based on the degree of contribution to the quality of life. Thus, a brand new measure was created. The author received a buy-off on the idea from all panel members. Panel members agreed to call this new measure quality of life index.

6. Comprehensive value hierarchy was put together by the author based on all the responses from panel members.

    a. Author received buy-off on comprehensive hierarchy and measures from all the panel members.

7. Panel members assigned weights to measures in the hierarchy.

    a. Author collected all the measures and averaged them.
    b. Buyoff was received from all panel members on the final averaged distribution of weights.

8. SDVFs were explained to panel members.

    a. Panel members agreed with the author that categorical functions should be used for all measures for ease of use.
    b. Constructed and received concurrence on all categorical SDVFs.

9. Action item: discussions will have to be conducted with panel members assigning the quality of life scores to common facilities found in UFC 4-020-01 Table 3-1. These scores will make up the quality of life index.

Appendix D: UFC 4-020-01 DoD Security Engineering Facilities Planning Manual Table 3-1

Common Facility Types

Baseline Building Category	Facility Type	Examples
Administrative and Community Support Buildings *	Headquarters and Operations Facilities and Other Administrative Facilities	Brigade, Battalion, Company Headquarters
		Airfield Operations Facility
		Aviation Unit Operations Facility
		Field Operations Facility
		Ship Operations Facility
		Emergency Operations Facility
		Fire / Police Station
		National Guard / Reserve Centers
		Cargo Handling Office
		Dispatch Building
		Courtroom
		General Administrative Facility
	Schools and Education Facilities	Education Center
		Dependent School
		Religious Education Center
	Community Facilities	Community Service Center
		Child Development Center
		Drug / Alcohol Abuse Center
		Red Cross Building
		Craft Centers
	Small Retail Facilities	Shoppette
		Golf Clubhouse
		Laundry
		Video Rental Store
Unaccompanied Personnel Housing *	Unaccompanied Personnel Housing	Enlisted Barracks / Dormitories
		Trainee Barracks / Dormitories
		Transient Unaccompanied Personnel Housing
		Unaccompanied Officers / Enlisted Personnel Housing
Family Housing	Family Housing	Family Housing Units
Dining Facilities *	Dining Facilities	Dining Facilities
		EM Club

UFC 4-020-01 Table 3-1 Continued

Medical Facilities *	Medical Facilities	Hospital
		Medical Clinic
		Dental Clinic
		Pharmacy
		Veterinary Clinic
		Laboratory
Special Structures *	Religious Facilities	Chapel
	Recreation Facilities	Auditorium
		Gymnasium
		Bowling Alley
		Theater
	Commissaries and Exchanges	Commissary
		Exchange
	Alert Systems, Forces, and Facilities	Alert Systems, Forces, and Facilities
Maintenance Facilities (other than weapons)	Equipment Maintenance Facilities	Equipment Maintenance Facilities
	Aviation Maintenance Facilities	Aviation Maintenance Facilities
	Motor Pools	Motor Pools
	Aircraft Parking Areas - hangars	Aircraft Parking Areas
	Ship or Boat Berths	Ship or Boat Berths
	Arms, Ammunition, and Explosives Storage Facilities	Magazines
		Arms Rooms
		Weapons Maintenance Facilities
	Petroleum, Oils, and Lubricants Storage Facilities	Petroleum, Oils, and Lubricants Storage Facilities
	Research and Development Facilities	Research and Development Facilities
	Warehouses	Warehouses
	Utilities and Substations	Utilities and Substations
* Building types included in cost tables in Appendices A - C		

Appendix E: 412th CEG Panel QLI Scores Table

Facitility	QLI Score Member #6	QLI Score Member #5	QLI Score Member #2	QLI Score Member #7	QLI Score Member #4	QLI Score Member #3	QLI Score AVERAGE
Brigade, Battalion, Company Headquarters	1	3	4	0	3	3	2
Airfield Operations Facility	2	2	5	1	2	3	3
Aviation Unit Operations Facility	1	1	5	1	1	3	2
Field Operations Facility	1	1	5	1	1	3	2
Ship Operations Facility	1	1	4	1	1	3	2
Emergency Operations Facility	1	3	5	2	3	3	3
Fire / Police Station	4	3	5	3	3	3	4
National Guard / Reserve Centers	1	2	3	0	2	2	2
Cargo Handling Office	1	1	3	0	1	3	2
Dispatch Building	1	2	3	0	2	3	2
Courtroom	1	3	3	3	3	2	3
General Administrative Facility	3	3	4	1	3	3	3
Education Center	3	5	5	4	5	4	4
Religious Education Center	2	5	4	2	5	4	4
Community Service Center	4	5	5	4	5	4	5
Child Development Center	5	5	5	4	5	5	5
Drug / Alcohol Abuse Center	2	4	3	2	4	3	3
Red Cross Building	3	4	2	2	4	3	3
Craft Centers	3	4	2	3	4	4	3
Enlisted Barracks / Dormitories	5	5	5	3	5	5	5
Chapel	5	4	4	4	4	4	4
Auditorium	1	4	4	2	4	4	3
Gymnasium	5	5	5	4	5	4	5
Theater	4	4	3	3	4	4	4
Alert Systems, Forces, and Facilities	2	3	4	1	3	3	3
Equipment Maintenance Facilities	3	2	3	0	2	3	2
Aviation Maintenance Facilities	3	2	5	0	2	3	3
Motor Pools	2	2	3	1	2	3	2
Aircraft Parking Areas	1	1	5	0	1	3	2
Magazines	1	1	5	0	1	2	2
Arms Rooms	1	1	5	0	1	3	2
Weapons Maintenance Facilities	1	1	5	0	1	3	2
Petroleum, Oils, and Lubricants Storage Facilities	2	1	2	0	1	2	1
Research and Development Facilities	1	1	2	1	1	3	2
Warehouses	2	1	3	0	1	3	2
Utilities and Substations	5	3	5	0	3	3	3

Appendix F: Extracts of Relevant Paragraphs from the Air Force Publications that Guided Formation of Tier 1 Values of the VFT Hierarchy

According to *AFI 32-1032, PLANNING AND PROGRAMMING APPROPRIATED FUND MAINTENANCE, REPAIR, AND CONSTRUCTION PROJECTS paragraph 1.2.6.* Installation Commander: "*Installation commander assisted by the BCE (Base Civil Engineer) is responsible for "…planning and programming all O&M-funded, maintenance, repair, and UMC for real property requirements necessary to properly support assigned missions and people…"*

According to *AFI 32-1001 CIVIL ENGINEER OPERATIONS paragraph 4.1. Overview*: "*… Asset Management translates Air Force objectives into asset-related decisions by understanding assets' physical attributes, condition, usage, and performance as well as the realized and potential value to the mission. When applied correctly, asset management balances risk, current, and future Air Force objectives, resource limitations, and lifecycle management. Real property asset management should:*

> *4.1.1. Provide an understanding of how each asset contributes to mission accomplishment.*
>
> *4.1.2. Manage and invest in assets to optimize mission accomplishment.*
>
> *4.1.3. Focus on cost-effective infrastructure management across the entire life cycle of assets.*
>
> *4.1.4. Develop and grow a culture of effective, risk-based, mission-focused decision making through training, professional development, education, and leadership support at all levels."*

According to *Air Force Policy Directive 32-10 INSTALLATIONS AND FACILITIES Summary of Changes Paragraph 1.4: "1.4. Determine levels of investment for installations and facilities based on the following general priorities: statutory and regulatory compliance, other legal requirements including treaties and host-nation agreements, enhanced mission capability, improved living and working conditions and other requirements to ensure the best return on investment."*

References

AFCEC (2019). *FY21-25 AFAMP Business Rules*. AFCEC.

AFCEC. (2022). *Air Force Civil Engineer Sustainment Management Systems Playbook*. AFCEC.

Antelman A., Dempsey, J.J. and Brodt, B. (2008). *Mission dependency index - a metric for determining infrastructure criticality*. International Facility Management Association Facility Management Workshop 2008. Washington, DC. DOD. (2013, September 30). Department of Defense Base Structure Report.

Bortoluzzi, M.; Furlan, M.; Colombo, S.G.; Amaral, T.M.; de Souza, C.C.; dos Reis Neto, J.F.; de França, J.F. *Combining Value-Focused Thinking and PROMETHEE Techniques for Selecting a Portfolio of Distributed Energy Generation Projects in the Brazilian Electricity Sector*. Sustainability 2021, 13, 11091. https://doi.org/10.3390/su131911091

Cox, Steven M. *Ranking and Generating Alternatives for the National Air Intelligence Center's (NAIC) Resource Allocation Strategy*. MS thesis, AFIT/GOA/ENS/97M-03. School of Systems and Engineering Management, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, March 1997.

Dempsey, J. J. (2006). *Facility asset management doctrine. A Strategy for making better decisions at lower risk and costs*. Federal Facilities Council's Forum, 1-7

Dyer, James S. *A Methodology for the Analysis and Selection of Alternatives for the Disposition of Surplus Plutonium*. Amarillo TX: Amarillo National Resource Center for Plutonium, August 1999 (ANRCP-1999-23).

Dyer, James S., Thomas Edmunds, John C. Butler, and Jianmin Jia. *A Multi-attribute Utility Analysis of Alternatives for the Disposition of Surplus Weapons-Grade Plutonium*, Operations Research, 46: 749-760 (November / December 1998).

Fogleman, *Ronald R. Message to Air University*, 23 December 1994.

Gao S., Li Y., Guo H. (2018) *Understanding the Value of MOOCs from the Perspectives of Students: A Value-Focused Thinking Approach*. In: Al-Sharhan S. et al. (eds) Challenges and Opportunities in the Digital Era. I3E 2018. Lecture Notes in Computer Science, vol 11195. Springer, Cham. https://doi.org/10.1007/978-3-030-02131-3_13

Grussing, M. & Uzarski, D. & Marrano, L. (2006). *Condition and Reliability Prediction Models Using the Weibull Probability Distribution*. 19-24. 10.1061/40799(213)4.

United States Air Force. (2014). *Programming Plan (P-Plan) Revision 1 for Implementation of Enterprise-Wide Civil Engineer Transformation (PAD 12-03), Volume 1.* Headquarters United States Air Force.

Jackson, Jack A., Brian L. Jones, Lee J. Lehmkuhl, Harry W. Conley, and John Andrew. (1997). *Air Force 2025 Operational Analysis*, Military Operations Research, 3: 5-20.

Jurk, David. (2002). *Decision Analysis With Value Focused Thinking as a Methodology to Select Force Protection Initiatives for Evaluation*. MS Thesis. Air Force Institute of Technology, Ohio, USA.

Keeney, R. L. (1992). *Value-Focused Thinking: A Path to Creative Decisionmaking*. Cambridge: Harvard University Press.

Keeney, Ralph L. *Creativity in Decision Making with Value-Focused Thinking*, Sloan Management Review, 35: 33-41 (Summer 1994).

Kirkwood, C. W. (1997*). Strategic Decision Making Multiobjective Decision Analysis with Spreadsheets.* Duxbury Press, Belmont, CA, 1997.

Kujawski, E., & Miller, G. (2009). *The Mission Dependency Index: Fallacies and Misuses*. In INCOSE International Symposium (Vol. 19, pp. 1565–1580). Wiley Online Library. Retrieved from: https://www.researchgate.net/publication/285405545_The_Mission_Dependency_Index_Fallacies_and_Misuses

McElroy, R. S. (1999). Update on national asset management initiatives: facilitating investment decision-making. In *Innovations in Urban Infrastructure Seminar of the APWA International Public Works Congress* (pp. 1–10). Citeseer. Retrieved from: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.58.316&rep=rep1&type=pdf

Nadine Barrett-Maitland, Corlane Barclay & Kweku-Muata Osei-Bryson (2016) *Security in Social Networking Services: A Value-Focused Thinking Exploration in Understanding Users' Privacy and Security Concerns, Information Technology for Development,* 22:3, 464-486, DOI: 10.1080/02681102.2016.1173002

Nichols Matthew J. (2015). *A Delphi Study Using Value-Focused Thinking For United States Air Force Mission Dependency Index Values.* (Theses and Dissertations). Air Force Institute of Technology, Ohio, USA.

Nicholas, John & Steyn. (2017). *Project Management for Engineering, Business and Technology* (5th ed.). London, UK & New York, NY: Routledge.

Madaus, M. W. (2008). *Asset Management Optimization*. Unpublished manuscript.

Parnell, G. S. (2007). *Value-focused thinking using multiple objective decision analysis*. In: Methods for conducting military operational analysis: Best practices in use throughout the Department of Defense, 619-656.

United States Air Force. (2013). Air Force 2023 Implementation Plan. Headquarters Air Force.

Smith, Clark W. (2016). *Mission Dependency Index of Air Force Built Infrastructure: Knowledge Discovery with Machine Learning.* MS Thesis. Air Force Institute of Technology, Ohio, USA. https://scholar.afit.edu/etd/412

Shoviak, M. J. (2001). *Decision Analysis Methodology to Evaluate Integrated Solid Waste Management Alternatives For a Remote Alaskan Air Station*. MS Thesis. Air Force Institute of Technology, Ohio, USA.

Teicholz, E., Nofrei, C., & Thomas, G. (2005). Executive order# 13327 for real property asset management. IFMA Journal, November/December. Retrieved from http://www.graphicsystems.biz/gsi/articles/ifma_executive_order13327.pdf

Tshering, G. and Gao, S. (2020), *Understanding security in the government's use of blockchain technology with value focused thinking approach*, Journal of Enterprise Information Management, Vol. 33 No. 3, pp. 519-540. https://doi.org/10.1108/JEIM-06-2018-0138

Uddin, Hudson & Haas. (2013). *Public Infrastructure Asset Management* (2nd ed.). New York, NY: McGraw Hill Education.

Weniger, R. (2018, Spring). Setting Priorities: Tactical MDI Aligns Facilities to Mission. *Air Force Civil Engineer, Vol. 26*(1), 10-13.

Westinghouse Electric Corporation. 1986. Phase 1 Study of Metallic Cask Systems for Spent Fuel Management from Reactor to Repository. Report WTSD-TME-085. Madison, Pa.: Westinghouse Waste Technology Services Division.

Winthrop, Michael F. *Technology Selection for the Air Force Research Laboratory Air Vehicles Directorate: An Analysis Using Value Focused Thinking*. MS thesis, AFIT/GOR/ENS/99M-18. School of Systems and Engineering Management, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, March 1999.

Vita

Bayram Kurbanov graduated from California State Polytechnic University in Pomona with a Bachelor of Science degree in Civil Engineering in June 2011. After college, he got hired by Kiewit Infrastructure West Company Southern California District to work as a Field Engineer on the I-405 Sepulveda Pass Widening Project. He spent the following three and half years of his life working at Kiewit on I-405 and various other smaller projects throughout Southern California. After Kiewit, Bayram spent a year working at Advanced Engineering and Consulting as a design engineer working on land development projects for residential and commercial construction in the county of Los Angeles. In 2016, Bayram was hired by the 412th Civil Engineer Group at Edwards AFB in California as a General Engineer. In that position, his main responsibilities at Edwards AFB were project management and contracting officer representative for construction projects. Bayram transitioned into the role of the Base Energy Manager in 2021. His current duties include utility management, base energy and water conservation, and enhancement of base energy resilience.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From - To)*

4. TITLE AND SUBTITLE	**5a. CONTRACT NUMBER**
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	**5d. PROJECT NUMBER**
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	**8. PERFORMING ORGANIZATION REPORT NUMBER**
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	**10. SPONSOR/MONITOR'S ACRONYM(S)**
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			**19b. TELEPHONE NUMBER** *(Include area code)*