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Analyze the Air Force Methods for Facility Sustainment and Restoration

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FACILITY SUSTAINMENT AND RESTORATION

THESIS

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ANALYZE THE AIR FORCE METHODS FOR FACILITY

SUSTAINMENT AND RESTORATION

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My number one goal in entering this degree program was to provide positive results for the United States Air Force. I searched out a topic that I felt would result in a process improvement for the AF. Although the results were not as successful as I would have hoped, I feel that in some small measure I did provide some positive measures to AF facility management. This effort, though, was definitely a team effort and I would like to acknowledge those individuals that greatly assisted this effort.

First, there was Lt Col Heidi Brothers, my thesis advisor. Lt Col Brothers was very interested in my topic, having advised others on similar subjects, and was a great assistance in directing me to pertinent research. She was excellent at keeping me on track in completing this effort and was meticulous in editing the final product. Next, I would like to thank my other committee members. Major (select) Teri French was the facility management expert at the CE schoolhouse and was a great source of current information and often directed me to people that could assist my research. Mr. William T. Marsh works at Headquarters AFMC/CEPD, as the head of the programming branch, and was instrumental in the development of my research as well as coming up with the original idea for the topic. I struggled with narrowing a topic during my initial literature search and Mr. Marsh suggested looking at a restoration model. Lt Col Marc Pincince was my contact at Headquarters USAF/ILE and although he was not a member of my thesis committee, he provided me with an incredible amount of data and assistance that made this research possible.

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ABSTRACT

The Department of Defense (DoD) is improving the procedures for identifying, advocating, allocating funding, and accomplishing facility requirements to improve the readiness capability to support the mission. The purposes of this research were to fully explore the methodologies employed by the Air Force (AF) and try to capitalize on industry standard practices to improve the AF methods. Industry has conducted extensive research devoted to the development of predictive models to estimate facility maintenance or sustainment requirements. The DoD and the AF have already implemented the facility sustainment model (FSM) to predict facility sustainment requirements; now however, they are struggling with a justifiable methodology for predicting facility repair or restoration requirements. This research used statistical stepwise regression with historical AF facility requirement cost data for the last five years, in an attempt to develop a predictive model. The analysis results were not significant and did not result in an accurate predictive model, but the methodology and background research did produce some positive results. Observations regarding AF facility requirement reporting tools were identified and recommendations for improved integration were made in the research.

ANALYZE THE AIR FORCE METHODS FOR FACILITY SUSTAINMENT AND RESTORATION

I. INTRODUCTION

Air Force (AF) installations are the architecture that support mission operations worldwide, and it is essential that they be maintained in a manner that provides maximum readiness potential. The AF operates and sustains a $196 billion physical plant consisting of over 731 million square feet of facilities on 166 installations in the world (49:1). The facilities and infrastructure that make up the physical plant are the platforms that enable the Air Force to project military power around the globe, supporting joint and coalition operations during wartime and during peacetime operations and contingencies. AF facilities and infrastructure are durable capital assets, which if properly built and sustained, have life cycles ranging to 50 years and beyond. The physical plant of the AF is aging rapidly, averaging forty years in age, with 25 percent of the physical plant over 50 years old (49:6).

Substantial resources are required to sustain this vast inventory, which include: sustainment resources for normal recurring maintenance and cyclical repair requirements; restoration resources for repair requirements that occur when sustainment is not accomplished; modernization resources for major renovation requirements; and new mission resources which are usually funded with military construction (MILCON) dollars. Another term commonly used is operations and maintenance (O&M) resources which usually funds sustainment, restoration, and modernization requirements. In FY

2001, the AF has identified over $38 billion in restoration and modernization requirements, with over $18 billion of that amount necessary to restore facilities and infrastructure to a minimum acceptable performance level. (49:18). The AF needs to focus limited resources on keeping only the infrastructure absolutely required, sustaining that infrastructure, and modernizing when necessary to meet current and future needs (27:II)

1.1 Installations and Facilities in Support of Military Readiness

In the late 1980s and early 1990s, the MILCON and O&M funding streams were steady and substantial, enabling installations to provide quality facilities and modernize supporting infrastructure (49:8). Since then, the Department of Defense (DoD) and specifically the AF have experienced declining budgets as funds are redirected to support weapon system modernization. As a result, a substantial backlog of restoration and modernization requirements has emerged. The AF has struggled to identify, document and justify all of the real property sustainment, restoration and modernization requirements at its installations.

Although the DoD infrastructure has been reduced by 30% since the Cold War, the military is engaged in 165 percent more missions (27:7). This increased operations tempo has put a significant strain on remaining physical infrastructure without sufficient sustainment. In order to keep up with the rise in operations tempo, the DoD has engaged in weapon system modernization to maximize the effectiveness of existing personnel and resources. However, focusing on weapons system modernization has been at the expense of infrastructure and facility sustainment (maintenance and cyclical repairs), restoration (repair) and modernization (minor construction and MILCON) investments.

Operational effectiveness of the AF begins with quality facilities and infrastructure. The AF, although it has substantial reach, is inextricably tied to the facilities and infrastructure that support the weapons systems in use today. Facilities and infrastructure are continuing to degrade due to inadequate manpower and funding for real property sustainment and military construction (MILCON). Continued inadequate RPM, both materials and services, and MILCON investment levels could result in the failure of facilities and infrastructure system (11:19). This could severely impact the installations ability to perform the overall mission.

1.2 Classification of Requirements and Funding Categorization

The DoD divides facility requirements into three different classifications of work; maintenance, repair, and minor construction. These classification correspond to the three types of funding categories; sustainment, restoration, and modernization. Sustainment includes regularly scheduled adjustments and inspections, preventative maintenance tasks, and emergency response for minor repairs. It also includes major repairs or replacement of facility components that are expected to occur periodically throughout the facility life cycle (i.e. roof repair/replacement) (17:2). The DoD classifies sustainment as maintenance and repair activities necessary to keep a typical inventory of facilities in good working order over a 50-year service life.

Restoration requirements are items that address the failure of facility components that have been improperly maintained or repaired and also include significant repair items to restore a facility after being damaged by acts of God or by war. Restoration also includes repair items that occur out of the normal life cycle of a facility in order to bring the facility components back to original intended functionality (i.e. if a roof experiences a structural collapse because it had not been properly sustained and water damages the structural members, the roof replacement is considered sustainment while the repair of the structural members is classified as restoration) (49:15).

Finally, modernization is modifying existing facilities or constructing new facilities to meet new requirements, including those driven by new laws or codes, as well as meeting current technological requirements (i.e. new network computer system) (49:15). This classification of work can include construction of new facilities as well as major renovation of existing facilities to change or significantly modify the current use. Major renovation is often accomplished with military construction (MILCON) funding.

Recapitalization is defined as major renovation or reconstruction activities, including replacement of individual facilities, necessary to keep an existing inventory of facilities modern and relevant in an environment of changing standards and missions. Recapitalization extends the service life of facilities or restores lost service life; it includes both restoration and modernization, but excludes sustainment and new acquisitions (15:15).

1.3 Reporting and Advocacy Tools

The AF currently has several reporting and advocacy tools that are used to identify facility requirements, categorize the requirements, and report the requirements to decision makers that can appropriate funding to fulfill the requirements. The advocacy tools provide a systematic justification for the requirements and provide a clear and understandable picture of the mission impact of those requirements. Five tools/systems will be introduced and explained in depth in Chapter 2, they are the Automated Civil Engineer System (ACES), Facility Sustainment Model (FSM), Facility Investment Metric

(FIM), Installation Readiness Report (IRR), and the Facility Recapitalization Metric (RPM).

In FY 2000, the DoD developed the FSM to address the need for standardization across the services in identifying and funding sustainment. The FSM establishes an average annual amount of funding required to sustain a facility type over its life span. Since facilities vary greatly in both use and type of construction, the FSM takes this into account by combining similar real property category codes into broader classes called facility analysis categories (FACs), each with a different estimated annual sustainment cost. Also, the sustainment costs are adjusted for location, since labor and material costs are significantly different from location to location. After the sustainment costs are assessed, the FSM is used to estimate, advocate, and allocate sustainment funding requirements. Allocation refers to the division and distribution of funding to accomplish the requirements. When used at a Major Command (MAJCOM) level, the forecasted funding level from the FSM should (on average) be adequate for all the facilities and infrastructure sustainment requirements within the MAJCOM. These forecasts are not accurate down at the facility level due to fluctuations in annual sustainment requirements that average out when considered at the macro level (16:2).

Since 1998, the AF has used the Facility Investment Metric (FIM) to identify and advocate for restoration and modernization funding. The main purpose of the FIM is an advocacy tool, to identify the mission impact associated with each existing facility and infrastructure restoration and modernization requirement (12:1). FIM divides requirements by mission areas based on real property records and assigns mission impact ratings to those requirements. FIM is composed of all facility restoration and modernization requirements that are not classified as MILCON. The report rolls the requirements together into different classes, by mission area and mission impact, in order to provide a quick snapshot of total requirements in the AF. FIM is strictly an identification and advocacy tool that reports requirements and justifies them; it is not used to allocate resources once funding is appropriated.

The FIM data comes directly from the automated civil engineering system – project management (ACES-PM) database. Installations input project requirements into ACES-PM, coding them in accordance with FIM specifications, and forward the requirements to higher headquarters to be used in identifying and justifying funding requirements. HQ USAF/ILE takes the combined FIM data and distributes the total across the five-year budget planning horizon. This method is not easily defendable beyond the justification of the requirements themselves. Senior leaders take the FIM data and wrap it together with other O&M requirements to advocate for funding during congressional hearings. The resulting appropriations and subsequent military budget does not specifically identify FIM requirements to be paid for the past several years, higher priorities have superceded FIM requirements in the allocation process, such as diverting resources to fund new weapons platforms. The end result is that necessary restoration and modernization requirements continue to go unfunded and facility deterioration escalates. The DoD realized the importance of fully funding sustainment in establishing the FSM, yet the restoration requirements have not been specifically addressed and continue to be deferred.

The FIM data is also incorporated into the recently implemented Installation Readiness Report (IRR). To comply with Section 117 of Title 10, United States Code, the AF submits the annual IRR to Congress. The report identifies the capabilities of AF facilities and infrastructure to support forces in the conduct of their mission (49:5). The FIM, FSM, and other data are combined to come up with the IRR, which is then submitted for congressional review. This installation report is an integral element of the Defense Readiness Reporting System, which Congress uses in justifying annual defense programs and appropriations. The IRR is also used to justify facility requirements in the program objective memorandum (POM) process. The DoD uses the POM process in estimating future funding requirements and submitting them for congressional approval.

Figure 1 illustrates the structure of the reporting and advocacy tools and how they are interrelated. All of these tools are tied into the ACES database, which is the primary information management system that AF civil engineers use. ACES provides the data and key references for each advocacy tool, and acts as the interactive link between the tools. The tools use the ACES information in different ways.

The different tools track the information extracted from ACES in different ways. For each facility requirement, FIM identifies specific ratings related to the severity of mission impact if the requirement is not corrected. The IRR, on the other hand, uses nine different facility classes and combines individual facility requirements into a lump sum per facility class in order to determine the impact rating for the entire facility class. This difference in terminology is confusing since both tools use the term mission impact, but arrive at the mission impact in entirely different ways. Articulating the impact using FIM is relatively easy for Wing Commanders because each project is judged independently, but with the IRR, the impact rating is dependant on the cost of the requirement compared to the overall plant replacement value (PRV) of the facility class. The PRV is the total cost to replace facilities at and installation at any given time.

Classification of Requirements	**TOOLS**			
	ACES	**FSM**	**FIM**	**IRR**
Sustainment	ACES-Ops module is pending, will handle scheduling recurring, preventative, and emergency maintenance, ACES-PM also identifies sustainment and study requirements	Macro level tool for identifying an allocating sustainment funding levels to meet installation level requirements	Not covered	Sustainment is a component of the overall requirements reported to Congress
Restoration	ACES Real Property (RP) module provides basic facility information (facility number) that ties to the PM module that inputs actual facility restoration requirements	Not covered	Tool that takes base level information and combines all AF requirements together to be used as an advocacy tool to justify funding based on mission impact	Restoration projects are included in the IRR and provide some of the requirement that drive the mission impact ratings
Modernization	Modernization requirements are inputted to ACES-PM, provides the electronic format for preparing formal documentation for Congressional approval	Not covered	Tool identifies new mission and recapitalization requirements at base level, combines all AF requirements together to be used as an advocacy tool to justify funding	Modernization projects, indicating new or revised missions, provide the bulk of the requirements inputted to the IRR which significantly impacts the mission ratings, often accomplished with MILCON funding
Users of Data	Base Level CE, but also used at all levels for reporting efforts	Base Level CE MAJCOM Program Managers (PMs) Air Staff PMs	Base Level CE MAJCOM PMs Air Staff PMs	MAJCOM PMs Air Staff PMs Congressional Staffers

Figure 1. Structure of Reporting and Advocacy Tools

1.4 Research Questions

This research delves into the issues associated with facility sustainment and restoration approaches and methods used by the AF. The AF uses a base level management information system (ACES) that is used as the primary source of information for the different reporting tools, like FSM, FIM, and IRR. The issue at the heart of this research is that the FIM database has the potential to not only adequately identify requirements, but it may be used to articulate future requirements in an easily defendable and justifiable manner. FIM requirements are combined, from installation level to MAJCOM, and then compiled into an AF total matrix. Air Staff program managers break up the total FIM requirements across the five-year fiscal year planning document (FYDP). This process means at best that a random 1/5 of the requirements will be submitted for any one year of the FYDP. However, funding the FYDP is impacted by politics and often is adjusted each year and funding is diverted to weapons system modernization requirements. This results in a continued degradation in already older facilities, significantly affecting the facilities ability to meet mission requirements, also, it costs more to invest in the future.

The funds distributed for facility maintenance each year is dependant on these other requirements competing for the same funding, regardless of what the true annual requirements may be. Due to this, FIM is used strictly as an advocacy tool and is not used to allocate resources. Therefore, the primary objectives for this research include:

- Improve the FIM tool and augment its use as an advocacy tool with the ability to be used for an allocation tool
- Utilize existing historical FIM data to develop a predictive model for restoration requirements
- Improve the integration of the different advocacy tools and suggest common terminology that would reduce confusion when discussing the results with AF decision makers

To meet these objectives, this research will attempt to answer the following research questions.

1. What facility restoration requirements variables in FIM data are the most significant and can be used to develop a model to make funding projections to be used in the AF POM process?

2. How can the FSM, FIM, IRR, and ACES reporting tools be adjusted to be more compatible and integrated?

1.5 Research Methodology

The first step in understanding the AF facility requirements process is to understand all of the systems and tools that encompass that process, including the ACES, FSM, FIM, and IRR. Each information database tool needs to be examined and compared in order to understand how the tools interrelate and communicate requirements. The first question requires an in-depth analysis of the FIM information that identifies all restoration requirements in the AF. A statistical regression analysis will be accomplished to determine the key predictors that have the most significant impact on determining future restoration requirements funding levels using the last five years of requirements reported in the FIM database. This analysis will only provide a macro level model to be used for projecting restoration requirement levels; much like the FSM is used for projecting sustainment requirement levels. Once the model seems valid and accurate, additional data will be used to test and validate the model; then the model will be used to predict the FY2004 restoration requirements.

This research will also provide recommendations to decision makers on how the existing reporting tools can be improved. Attempts will be made to integrate the reporting tools together into a single tool that is easier to use by installation representatives. Terminology differences between FIM and IRR are difficult to explain to installation leadership. The differences in mission impact and facility classifications cause the tools to be misunderstood; efforts are under way by HQ USAF/ILER to adjust the FIM mission areas to align more closely with the IRR facility classes. These differences need to be identified and other possible solutions developed to integrate the tools and make them more compatible.

1.6 Scope of Research

This research attempted to develop a predictive model for estimating facility restoration requirements and also explored the various reporting tools used by the AF in an attempt to provide recommendations for improvement and integration. Statistical stepwise regression analysis was used in the effort to develop the predictive model, using a database that was limited to five years of FIM requirements and a snapshot in time of the overall AF real property database or PRV taken in FY 2000. Although the FIM databases contained all types of facility requirements, the scope of this research was focused on the restoration (repair) costs. Using the stepwise regression, significant facility specific variables emerged that could possibly contribute to the accuracy of a predictive formula. The FSM, FIM, IRR, and FRM are the AF reporting tools that were evaluated in this research as well as their origins in the ACES database. The tools are used to advocate and/or allocate resources and need to be properly integrated and express the same story to decision makers.

1.7 Review of Chapters

Chapter II provides a summary of the appropriate literature, both within the DoD as well as peer reviewed journals. It examines the current methodologies used by the AF Civil Engineers and Department of Defense personnel in tracking and reporting facility and infrastructure requirements. Chapter III discusses the methodology used when answering the research questions and describes how the research questions were answered. Details regarding the data analysis and procurement of the data are also explained. Chapter IV explains the results of the methodology and the findings of the research questions. This includes using the statistical results of the database analysis and attempting to use the predictive model as an allocation tool. In conclusion, Chapter V summarizes the research results, discusses limitations, and makes recommendations to improve the reporting requirements to further justify facility and infrastructure expenditures.

II. BACKGROUND

This chapter summarizes the literature relative to this research. The information is divided into four main sections: 1) a description of facility maintenance and industry methods for quantifying and accomplishing facility maintenance; 2) infrastructure importance to the AF; 3) facility life-cycle maintenance philosophy; and then an 4) analysis of how the Air Force approaches facility maintenance, explaining all the tools used. Evaluating industry approaches to facility management is very useful in examining the methods being used by the AF and dissecting where they should be adjusted and improved.

2.1 Industry Approach to Facility Maintenance

In the past two decades, extensive research has been accomplished regarding facility maintenance management. Due to the construction boom during and following World War II, a substantial amount of facilities and infrastructure in the United States are approximately 40-50 years old. Deterioration in these assets began to show in the mid-1970s in the wake of the economic downturn. The major investment since WWII had been in the construction of new facilities, not in the re-investment in the existing infrastructure, therefore that infrastructure continued to decay (29:25). It became obvious that underfunding capital renewal to offset facility deterioration led to the current backlog of deferred maintenance. The term "deferred maintenance" emerged in the 1970s as facility managers began to realize the magnitude of the neglect; the AF has substituted this term with deferred sustainment. Instead of accomplishing plant improvements using surplus or budgeted funding, many organizations were forced to correct facility deficiencies by borrowing funds against future projected revenue, resulting in significant debt. The result was more research and a higher interest in maintaining facility infrastructure (29:25). Research conducted by Ottoman, Nixon, and Lofgren (35), identified four approaches to estimating sustainment: plant value methodology, formula-based methodology, life-cycle cost methodology, and condition assessment methodology (35:72). Both industry and government officials use a variety of these methods in determining facility requirements, depending on the magnitude of plant value.

2.1.1 Plant Value Methodology

Plant value methodology is based on the premise that facility sustainment costs can be estimated on the basis of the original construction or renovation costs (35:72). This is a simplistic method, but is popular for organizations that have a large physical plant to manage, included numerous facilities and vast infrastructure. The annual difference in individual facility requirements tends to wash out when dealing with large inventories of facilities. Determining the plant value can be done in two ways. The first way is called the current plant value (CPV) that takes the initial construction or renovation costs of facilities/infrastructure and increases the value at an average inflation rate. The second method calculates the cost to replace the facility or infrastructure given new technology and construction methods, and is called plant replacement value (PRV). The Building Research Board recommended that 2 to 4 percent of the current replacement value for a substantial inventory of facilities (excluding major infrastructure) be allocated each year for routine maintenance and renewal (29:29). The main advantage of using the plant value methodology is the ease of computation, once the plant value is determined; the percentage allocated is the only factor that is used. That percentage, however, is difficult to justify to decision makers and makes this methodology challenging to advocate. The AF previously utilized this method until mandated to use the FSM, which is a formula based model. Starting in FY 1998, the AF O&M funding was limited to the minimum preventative maintenance level of 1 percent of the PRV due to funding constraints caused by other priorities. However, rarely did the full 1 percent ever reach the installation level and was actually applied to sustainment requirements. With the new FSM, although PRV is not considered, the amount allocated for facility sustainment actually rose to 1.3 percent of PRV (49:8). When considering the AF physical plant is worth $196 billion, a 0.3 percent increase is almost $600 million.

2.1.2 Formula-Based Methodology

The formula based methodology utilizes mathematical expressions to derive a particular outcome value for estimating facility sustainment costs. There are several different formula based models including: Dergis-Sherman formula, facilities renewal allowance, square footage model, as well as the AF facility sustainment model. These models utilize simple to complex mathematical equations to derive estimated facility sustainment costs. Often, simple variables, like facility age, facility area, initial facility cost, are used because they are readily available and simple to derive if accurate records are kept. Use of these simple variables increases the ease in using the model as well as the accuracy because the data is historical in most cases.

The Dergis-Sherman approach (43) indicates "all construction factors -- size, complexity, materials, special features, and so on -- are conveniently reflected in construction costs." This approach assumes that a building's value and future maintenance and repair costs are directly related to the original construction costs and can be determined by compensating for age and inflation. Their formula, assuming a life cycle of 50 years, is:

$$\text{Annual Appropriation} = 2/3 \times BV \times BA/1{,}275 \quad (1)$$

Where BV = building value as an index inflated adjustment to the original cost; and BA = building age corrected for partial or total facility renewal. The 2/3 factor (building renewal constant) is based on the assumption that building renewal costs, on average, should be nor more than two-thirds of the cost of new construction. The 1,275 value is the summation of the 50 year digits (1 + 2 + 3 + … + 50 = 1,275) (35:75), this skews the distribution of estimated costs in the direction of older facilities (37:35).

This formula based methodology really began the research into trying to determine future facility requirements and to be able to articulate them in a logical manner. Although this methodology is simplistic, understanding the foundation of the formula and the rationale of the different constants was taken into account during this research and the development of the predictive model for restoration requirements.

A second formula based approach that deviated slightly from the Dergis-Sherman approach was the facilities renewal introduced by Phillips (37). His method earmarked funding every year for the eventual replacement of facility systems. He argued that facility planners need to recognize the aging of facilities and reserve some part of their replacement value each year against their future need for renewal. He divided facility systems into 25- and 50-year systems, where HVAC and roofing were examples of 25 year systems; plumbing, electrical, exterior walls, partitions, fire protection systems were classified as 50 year systems. Phillips used Dodge and Means System Costs estimating manuals to determine the replacement costs for each system (given a 25-yr or 50-yr service life depending on the system) and then used the formulas below to establish the renewal allowance that would be required each year.

$$\text{RA (25-yr)} = \text{BA}/325 \;\; \text{x} \;\; \text{Replacement Cost of 25-yr System} \qquad (2)$$

Where RA = renewal allowance and BA = building age at the time of analysis. The 325 value is the summation of the 25 year digits (1 + 2 + 3 + … + 25 = 325).

$$\text{RA (50-yr)} = \text{BA}/1{,}275 \;\; \text{x} \;\; \text{Replacement Cost of 50-yr System} \qquad (3)$$

Where RA = renewal allowance and BA = building age at the time of analysis. The 1,275 value is the summation of the 50 year digits (1 + 2 + 3 + … + 50 = 1,275) (37:35).

As with other estimating tools, the actual sustainment requirements of individual facilities may not match these estimates exactly, but given a large inventory of facilities, the specific requirements would average out over the entire inventory. The benefits of the facilities renewal allowance approach are that it is logical, it applies reasonable, if not provable, algorithms to measured data; it is convenient, it can be rapidly calculated and updated; and it is understandable, the theory is quite simple and easily articulated to decision makers (37:43). Phillips also introduces a slightly altered version to compensate for facilities that have been renovated, but the adjustment only applies to the BA portion of the equations above. This approach provides the justification for annual allocations to correct facility requirements.

The square footage model is the most simplistic of all because it multiplies a cost factor to the square footage of a facility or other unit of measure for an infrastructure system. The FSM is a variation of the square footage model but takes into account a location factor and an inflation factor. The cost factor in a square footage model is usually determined from historic data or industry standards, from such sources as Whitestone Research and R.S. Means cost guides (35:76). This type of model is best used when there is a large physical plant with numerous facilities or infrastructure systems to help average out the differences in annual requirements for specific facilities. This type of model is best applied when using historical data from within the organization that is attempting to predict sustainment costs. Often, the historical data is subject to the political philosophy of the organization and their economic stability (35:77).

2.1.3 Life-Cycle Cost Methodology

The life-cycle methodology breaks down a facility or infrastructure into subsystems and estimates the sustainment requirements at that level since each facility component requires different sustainment levels. System or equipment manufacturers provide estimated sustainment levels throughout the expected life and establish replacement schedules. This breakout allows estimators to input sustainment schedules for each subsystem and then roll them all together to determine the overall facility sustainment requirements. This methodology is very useful for facility managers that have a small facility inventory to manage and can take the time to input all of the estimated requirements.

One recent development that has assisted facility managers in utilizing this method is the use of computer maintenance management software (CMMS) (3:1). The facility manager can input the equipment and systems into the database, assign the recommended manufacturers sustainment schedule, and the program will define a sustainment schedule and cost estimates. The biggest obstacle confronting maintenance professionals is being forced to do more with fewer resources. Utilizing economical computerized maintenance management systems have helped meet this challenge and continue to evolve and improve (2:1).

Several companies provide CMMS systems, but they basically provide the same information. Differences revolve around the ease of inputting information into the system, and the accessibility of the reporting systems. The latest breakthrough is the use of CMMS through the Internet. This new application has significant potential. It provides cost-effective connection to remote sites and users, makes critical information available to others in the company that do not have the CMMS software, and makes electronic ordering available that directly links users to suppliers (44:44). The AF ACES Operations Module, discussed later, can be considered a version of CMMS. The operations module database has all the equipment/facility specific information for an entire installation and establishes maintenance requirements and schedules for preventative maintenance. This life-cycle cost methodology is very useful for determining sustainment requirements, but is not able to estimate restoration requirements if proper sustainment is not accomplished.

2.1.4 Condition Assessment Methodology

The condition assessment methodology begins by conducting an extensive condition assessment of the entire facility inventory and estimating component sustainment requirements. This can be very labor intensive and is usually used by facility managers with small facility inventories. The methodology involves a complete inspection with a checklist of facility components and each component is individually scored and maintenance requirements are determined. The level of effort required for this methodology is extensive and not cost effective for large facility inventories. The AF tried to use a version of this methodology when it implemented the Commander's Facility Assessment (CFA) in 1993 (42:6). Each facility was independently assessed and the mission impact was documented. The critical mission requirements identified in the CFA received the top priority, however, commanders began to notice that only critical mission requirements were being funded and began to inflate the facility assessment ratings to increase their funding. This philosophy shift reduced the credibility of the CFA and the program was adjusted in 1998 into the FIM.

2.2 Infrastructure and Facility ties to the Air Force Strategic Plan

The Air Force Strategic Plan (AFSP) establishes the guidance to ensure that near-term, mid-term, and long-term planning and programming move the Air Force forward toward achieving the Vision (13:1). The Air Force Vision is "Global Vigilance, Reach and Power"; global vigilance to deter threats, strategic reach to curb crisis and overwhelming power to prevail in conflicts and win America's wars (14:1). The AFSP, Volume 3, Long-Range Planning Guidance, charts the path of change for Air Force capabilities, people, infrastructure, and innovation (13:ii). The AFSP identifies six thrust areas which will lead to the desired capabilities needed by the future Air Force (10:25).

1) Develop Airmen of the Future
2) Aerospace Superiority
3) Find, Fix, Track, Target, Engage, and Assess
4) Expeditionary Aerospace Force
5) Capable and Credible Nuclear Deterrent Force

6) Shape Infrastructure of the Future Force

The Air Force Civil Engineer Strategic Plan (AFCESP) links the use of facilities and infrastructure to support the national strategy identified in the AFSP (10:15). The last thrust, "shape infrastructure of the future force," is the most directly impacted by civil engineering and the quality of facilities and infrastructure. Included in this last thrust is the goal to "create a right-sized infrastructure, to include bases, facilities, and support processes, to provide responsive and efficient support to global operations while ensuring quality of life and sense of community for Air Force personnel (10:26)." Civil engineering has two objectives in the AFCESP that directly support this thrust.

1) An efficient and effective base operating environment that maintains a strong sense of community and quality of life, and
2) A corporate process and a strategic direction for basing that reduces unnecessary cost and improves operational efficiency (10:26)

The Air Force civil engineers have identified five core competencies in the AFCESP to support all the applicable objectives identified in the AFSP: Installation Engineering, Expeditionary Engineering, Environmental Leadership, Housing Excellence, and Emergency Services. The Installation Engineering competency is the one directly tied to facility and infrastructure requirements. Installation Engineering competency is the sum total of activities needed to develop, operate, sustain, restore, and protect bases, infrastructure, and facilities (10:27). The AF civil engineers are responding to the AF Strategic Plan and will continue to evolve CE objectives as the plan changes with new threats.

2.3 Air Force Use of the Facility Life Cycle Cost Methodology

Using the life-cycle cost methodology described earlier, the AF has begun to evaluate new facility construction and renovation in terms of total facility life cycle cost and not just initial facility cost in order to reduce unnecessary costs and improve operational efficiency. The AF and other government agencies have recognized the importance of considering facility and infrastructure costs from cradle to grave. Life cycle costs assessment considers every aspect of a facility's expected service life, from original design and construction, operations and maintenance for the life of the facility, and eventually the final disposition costs once the facility has become obsolete. Ideally, organizations should replace or recapitalize the real property inventory, removing obsolete and excess structures and replacing them with new or modernized facilities, keeping the average age of facilities at a constant level.

The service life of facilities varies greatly depending on the type of facility, its usage and the sustainment investment it has received. The DoD has estimated that the theoretical service life of its average facility is 67 years (27:1). This estimate of 67 years assumes that those facilities receive proper sustainment and restoration throughout their life span. Without the proper sustainment and restoration levels, facilities deteriorate at a faster rate. Inadequate sustainment will erode facilities at a faster rate than if full sustainment is accomplished. Consequently, the service life of facilities is cut short and will result in an earlier need to recapitalize those facilities, either with new construction or major renovations, this is indicated in Figure 2.

Currently, the recapitalization rate for the DoD is over 100 years, well over the 67-year goal because of reduced funding (27:3). The result is facilities that are significantly beyond their expected service life, in extreme disrepair, costing more to keep operational than to just demolish. The average age of facilities and infrastructure continues to grow as a result of under-funding the recapitalization effort, cutting nearly six months off the life of facilities for every twelve months that pass (27:2). Figure 2 indicates this conceptual link between facility sustainment and recapitalization (49:12). A facility, when initially constructed, will perform at the optimum performance level for several years, however, with age, decay, and obsolescence; performance of the facility will steadily decline over the years even with proper sustainment. Without proper sustainment and periodic restoration, the point at which the facility reaches minimum acceptable performance occurs much quicker and significant capability is lost, indicated by the gray shaded area. This lost capability and earlier recapitalization cost is far greater in overall cost compared to funding full sustainment in the first place.

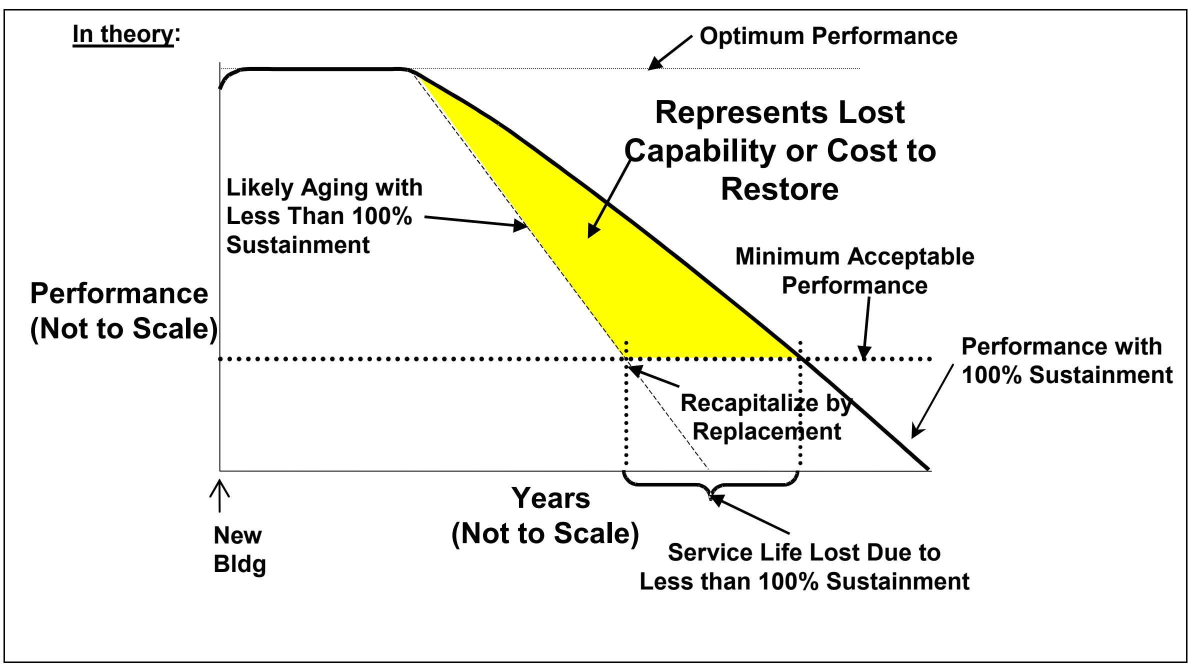


Figure 2. Lost Service Life Due to Inadequate Sustainment (4:12)

In fiscal year 2000, the DoD recognized that full facility sustainment was not being accomplished and that significant facility service life and capability was being lost. As a result, the DoD developed the FSM, and then instructed the services to fully fund sustainment of facilities at installations. Prior to this, the AF struggled for over a decade to properly fund facility sustainment levels. In 1998, sustainment funding was so scarce that it dropped to a preventative maintenance level (PML), referred to now as sustainment level, of 1 percent of the plant replacement value (PRV) (49:12). This 1 percent level was significantly lower than the 2 to 4 percent level recommended by the Building Research Board explained in Section 2.1.1.

Given the DoD mandate, the AF implemented the FSM strategy immediately, and allocated dollars to fully fund sustainment, which amounted to approximately 1.3% of PRV (49:8). However, due to the under-funding of requirements in the mid to late 90's, installations were forced to redirect sustainment funding to restoration and modernization projects, therefore continuing the increase in lost capability of existing facilities. It will take several years of above sustainment level funding in order to rebound from under-funding sustainment. In addition, MILCON appropriation levels have lagged behind recapitalization requirements to meet the 67-year goal, and some sustainment funding was redirected to accomplish minor modernization projects necessary for mission accomplishment. This redirection of sustainment funding compounds the problem and shortens the expected service life of existing facilities as indicated in Figure 2.

2.4 Fundamentals of Air Force Information Systems and Reporting Tools

The AF uses several different reporting tools to interpret the facility requirements contained in the ACES database. This section begins with an overview and history of the information management systems, from IWIMS to ACES, used by AF civil engineers and the different reporting tools. The FSM, FIM, IRR, FRM, which are used to articulate facility requirements, will then be described in-depth as each of these systems and tools are referenced throughout the rest of this research.

In the early 1990's, the AF realized that the physical infrastructure of installations was degrading faster than it was being repaired or recapitalized (replaced). Unfortunately, the Civil Engineering community, responsible for infrastructure management, did not have a clearly understood tool for advocating funding for these requirements. The first attempt by the AF to quantify these requirements was the Commanders Facility Assessment (CFA) in 1993, but this tool proved to be too subjective, because Commanders were given wide flexibility in assigning condition ratings for facility and infrastructure requirements, but often did not have the technical justification for the requirement (42:6).

In 1998, the AF replaced CFA with the Facility Investment Metric (FIM). The FIM was less subjective and concentrated on the individual project requirements and how they affected the mission of a particular installation. The FIM provides credible information to assist senior leaders in making key resource decisions in the facility and infrastructure business (12:2). FIM facility requirements were assigned mission impact ratings that were strictly defined and limited depending on the mission area of the facility. For example, a facility that directly supports the mission of the base, like a runway, can receive a critical mission impact rating, while a facility that only supports the community and does not directly impact the mission can rarely receive a critical impact rating except under special circumstances (like a child development project that provides special services for children during initial deployment call up). These specific definitions are explained in depth later in this section.

The FIM was designed to articulate facility requirements to decision makers and advocate for additional funding to correct those deficiencies. FIM guidance indicated that critical mission impact requirements would be completed first and only if funding is available would other requirements be accomplished. However, during the first year after FIM implementation, end of year expenditure reports revealed that installations were not correcting critical mission impact requirements first. Some installations were skipping over critical requirements for less mission impacting, quality of life projects. As a result, HQ USAF/ILE began tracking expenditures, and some MAJCOMs responded by using FIM as an allocation tool to distribute real property maintenance by contract (RPMC) funds to installations based on the FIM mission impact ratings. RPMC is a term that is used to describe how a requirement is contracted for accomplishment, and this term has since been replaced with the term sustainment, restoration, & modernization by contract (SRMC). Again, SRMC is the term that is used to describe the sustainment, restoration and modernization projects that are accomplished via a normal contracting mechanism.

Installations began to fund critical projects before degraded projects, which was the intent behind the HQ USAF/ILE pressure. In addition, HQ USAF/ILE held a programmers conference, called the FIM Integrated Process Team (IPT), attended by representatives from all the AF MAJCOMs where the facility requirements were reviewed and all of the critical mission impact requirements were thoroughly evaluated and justified to the satisfaction of all the attendees. This pressure reduced the flexibility of installation commanders to focus resources on what they determined was in the best interest of the installation. However, the value of FIM lies in the strict breakout structure of the mission areas and impact ratings, allowing every level of command to understand what is critical to meet the mission and this can be easily articulated to decision makers.

In 1998, Congress wrote into law that the DoD will prepare an annual installation readiness report (IRR) (49:5). The IRR was designed to provide congressional committees with an aggregate snapshot of the state of facility readiness in a particular service and what mission areas were the most degraded. The IRR initially tracked just the FIM requirements because they were easily extracted from the ACES database, however, the normal sustainment efforts were not being adequately captured and reported. In FY 2000, the DoD introduced the Facility Sustainment Model (FSM) after evaluating the different tools that the services used for identifying facility sustainment requirements; their intent was to standardize maintenance accounting and allocation across the services. This new model only considers sustainment requirements, so the AF continues using FIM to classify requirements that deal with restoration and modernization (17:2). The Army uses something called the Real Property Planning and Analysis System (not explored here), and the Navy uses a slightly modified IRR system, much like the IRR system to be discussed in a later section (40:3).

In FY 2002, the DoD developed and published the Facility Recapitalization Metric (FRM) to identify the ability of different services to meet their recapitalization requirements. The FRM is used to evaluate the projected funding levels identified in the FYDP and quickly determines if those levels will adequately recapitalize the facility inventory of a particular service. Each of these tools is discussed in depth below.

2.4.1 Automated Civil Engineer System (ACES)

The AF uses a central database, the automated civil engineering system (ACES), to populate the FSM, FIM, IRR, and FRM. The ACES information management system is being built using a relational database structure in a client/server configuration. Currently, Oracle database and a front-end client side consisting of Oracle forms and reports are being used. The ACES system replaced the former Work Information Management System (WIMS) and the Interim Work Information Management System (IWIMS) software for Project by Contract Management System (PCMS), Programming, Design, and Construction (PDC), and Environmental Project (A106) programming and management (9:1). Civil engineering squadrons at all AF installations use this information management system and the entire network is linked via Internet connections to a central database at Gunter Annex, Alabama. Users at all levels of management, from installation level civil engineers to MAJCOM and HQ USAF/ILE action officers, have access to base level facility project information. This system is the source data for all of the other reporting tools, including FIM, FSM, and IRR. The data includes items such as but not limited to: category code, facility number/address, units of the facility, type of construction, work history, installed equipment, current users, etc.

The ACES information management system is divided up into seven modules as indicated by Figure 3. Those modules are: RP, PM, fire department, housing, furnishings management office (FMO), personnel and readiness, and operations. All seven modules will be described in this section, but only the RP and PM modules were used in this research. These modules support the different flights within an installation level civil engineer squadron. Each module is tailored to track the data that each flight maintains and uses on a daily basis to accomplish the mission (38:27). All modules work in concert together and are thoroughly linked and accessible to all civil engineering personnel on an as-needed basis.

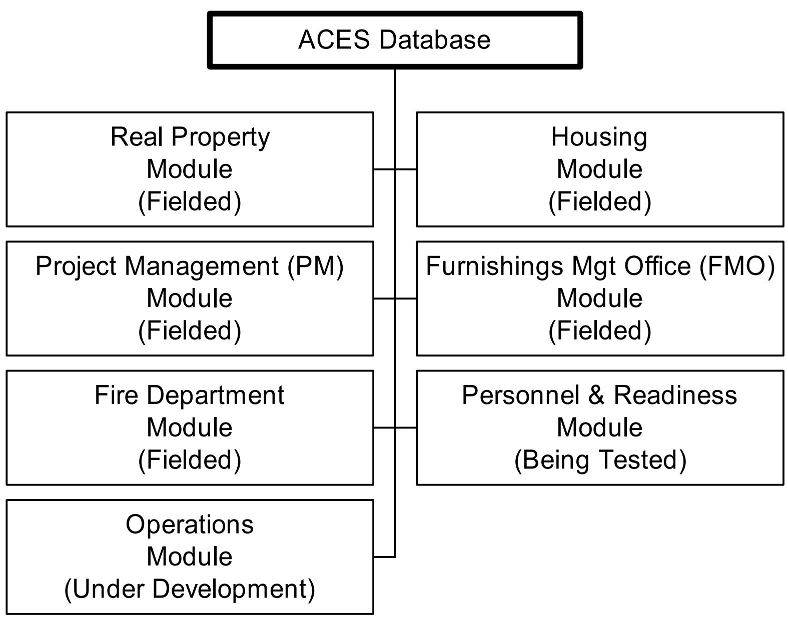


Figure 3. Automated Civil Engineer System

The first five modules have been fielded and are in use today. The RP module is the backbone of the database, will be used extensively in this research, and contains all facility specific information like facility number, square footage, building type, construction data and cost, as well as the facility users. The PM module contains facility project requirements with all three types including sustainment, restoration, and modernization. The information includes project number, current working estimate, construction timeline, mission area, mission impact, and other programming elements essential to developing the FIM. The fire department module contains data specific to fire protection, including extinguisher location and maintenance, suppression systems, and alarms. The housing module contains specifics for each military family housing unit and single occupancy dormitory on the installation. The FMO module tracks the furnishings that are provided at various installations, mostly dormitory furniture, but at some overseas locations, this database includes military family housing furniture as well.

Some components of ACES are either just being implemented or still under development. The personnel and readiness module is currently being implemented at installations (46:1). This module will track items like: squadron personnel and their current training status for contingency skills, contingency equipment, and unclassified contingency plan data. The operations module will be utilized to track facility sustainment requirements. Since the module is still under development, this research will make recommendations that may improve how ACES Ops module can help support the different reporting tools identified in this research. The ACES Ops system will accept and track job requests for sustainment, will contain the preventative maintenance data and requirements for all real property installed equipment (RPIE), provide recommended sustainment schedules, enable shop personnel to order/purchase equipment and materials, and will assist material handlers with an on-hand material database. Overall, the operations module will greatly assist facility maintenance personnel in their daily duties and schedules and is very similar to the CMMS databases used in industry. HQ AF Civil

Engineering Support Agency (AFCESA) is the lead agency in developing ACES and is currently developing the operations module, which they expect to field in the Fall of 2003 (45:1).

ACES is an enormous information management system. Installations from around the globe utilize the system and are all linked to the central database at Gunter Annex. Installation civil engineers populate the database with details regarding every facility and infrastructure system on base. The ACES-RP and PM modules contain the data that is extracted and used to populate the different reporting tools like FSM, FIM, and IRR. These reporting tools use ACES as a root database to generate management and executive level reports that identify the current state of facility capabilities at any given installation, MAJCOM, or even AF wide.

2.4.2 Facility Sustainment Model (FSM)

This section introduces the origins, purpose, and specifics of the FSM. The FSM is a new tool mandated by the DoD and implemented by the AF in 2000. The FSM is based on commercial research conducted by Whitestone Research (17:3). The purpose of the FSM is two fold; improve the requirements-generation process for sustaining facilities and; provide a standardized tool for assessment of sustainment programs (25:5). The FSM combines two quantitative measures, the category code of the facility and sustainment cost factor for that particular category code. The FSM derives sustainment cost factors from commercially available sources, like R.S. Means and Whitestone Research. The FSM converts the specific services (AF, Army, Navy) real property category codes into standardized facility analysis categories (FAC) (i.e., the AF category code for enlisted dormitories is 721-312, which is converted to a standardized FAC of

7210 used by all the services). These real property category codes are what distinguish facility types based on their use. The FSM divides the category codes up into nearly 400 FACs, each with a specific funding requirement or cost factor for each one (17:2). Some similar category codes are combined into a single FAC for ease of analysis. An example funding requirement for the dormitory FAC 7210 would be $3.63/square foot annually to sustain that facility for the expected service life (17). To further illustrate calculating the overall facility sustainment requirement, here is an example of the information and calculation.

Example: Suppose that we want to determine the annual sustainment cost for enlisted dormitories at Langley AFB, VA.

Total Facility Quantity at the installation = 16,000 SF (total square footage of all dormitories within this FAC on the installation)

Sustainment Cost Factor (from the handbook (17)) = $3.63/SF (annual cost to sustain this FAC)

Area Cost Factor for Langley AFB, VA = 1.12 (this factor is location specific and changes depending on economic conditions of the particular location)

Inflation Factor for the next fiscal year = 1.06 (6% estimated inflation for the upcoming year)

The formula for determining the funding requirements for each FAC is:

$$R = FQ \times SCF \times ACF \times IF \tag{4}$$

Where R is requirement, FQ is facility quantity (square footage, square yard, linear feet, each, etc), SCF is sustainment cost factor, ACF is area cost factor, and IF is inflation factor. Therefore, Requirement = 16,000 SF x $3.63/SF x 1.12 x 1.06 = $68,952.58

As a result of this FSM calculation, Langley AFB would warrant $69K to sustain the enlisted dormitories for the next fiscal year.

The above example indicates a subtotal for a single FAC on an installation; all of these independent FAC calculations are summed together to determine the total sustainment funding required for an installation.

This type of estimating using exact physical data combined with justifiable per unit cost factors is a form of cost factor methodology, explained in Section 2.1.2. This methodology provides a justifiable method of establishing estimated sustainment costs which is superior to the previously used percentage of plant replacement value due to the generalization across the entire inventory (17:3).

Most facilities and infrastructure are similar in the commercial sector as in the military; however, each military service has very specific facilities that are unique to a particular mission and are not readily comparable to commercial facilities. The FSM adjusts the sustainment cost factors for unusual facilities by taking into account similar commercial facilities and then adding in a unique cost factor. The FSM follows a simple methodology in determining which sources are appropriate for the development of the cost factors for different facility types:

1. Facilities with Identical Civilian Sector Counterparts – utilize standard off-the-shelf, commercially published sources (Whitestone Research) (i.e. a brick administration facility with a flat roof is the same in both the military and civilian sectors).
2. Facilities with Similar Civilian Sector Counterparts - cost factors that are applied to facilities with similar but not identical characteristics using commercial factors for

like facilities. (i.e. many of the category codes represented by the civilian sector are close but not exact, the closest match would be used in this case)

3. Unique Facilities with No Civilian Sector Counterpart – initial construction cost factor of the unique facility multiplied by ratio of sustainment cost factor to construction cost factor similar to Source 1 FAC (used for AF unique facilities) (17:4). (i.e. there are several military specific facilities like flight simulators or nuclear launch facilities that are military unique, facilities in the civilian sector that are similar are chosen and a cost factor is multiplied to bring the total sustainment level to a realistic amount)

The FSM is specific to sustainment only and does not include restoration and modernization projects. This tool is the primary means for advocating for and allocating sustainment funding to MAJCOMs, unlike FIM, which is currently used exclusively as an advocacy tool. Until the development of the FSM, the AF relied on the combination of PRV and FIM to derive necessary funding requirement levels, but sustainment, restoration, and modernization levels hovered at the basic preventative maintenance level of 1% prior to FY 2000. Once implemented, the amount identified by the FSM increased funding to approximately 1.9 percent of the plant replacement value, significantly greater that the previous levels (49:8). The funding provided, however, is directed to be spent on sustainment requirements, not to be deferred unless critical to the mission.

The FSM total funding requirement for each installation is derived from the ACES-RP module. The real property records identify the amount of units in each FAC (i.e. 4,000 SF of enlisted dormitory space) and are filtered by the FSM to determine the total funding requirements based on actual amounts of facilities and infrastructure. As a result, the accuracy of the real property records is essential to ensuring that installations have a current facility inventory and therefore receive correct amount of sustainment funding. However, since FSM only covers sustainment requirements, FIM remains as the only tool that captures restoration and modernization requirements.

2.4.3 Facility Investment Metric (FIM)

The FIM is a tool that the AF has been using since 1998 to identify, quantify, and advocate requirements to decision makers in the AF corporate structure and Congressional committees. The tool is used exclusively to define restoration and modernization facility requirements and advocate for funding for those requirements.

The FIM divides facilities and infrastructure into four facility classes or mission areas. The four are primary mission (PM), mission support (MS), base support (BS) and community support (CS). The classification of requirements is determined completely by the category code of the facility.

1. Primary Mission (PM) – facilities and infrastructure that directly accomplish or directly support the installation/tenant's primary mission (a tenant is defined as an organization on an installation that is not within the chain of command of that installation) (examples include airfield pavements, navigational aids, operational squadron operations centers, missile alert facilities, etc.).
2. Mission Support (MS) – Facilities that support the installation/tenant's primary mission, some infrastructure, and primary emergency response facilities. Primary emergency response facilities are limited to those facilities tasked to provide immediate life support and rescue services (examples include Central Security

Control, Fire Department, aircraft maintenance facilities, primary water and electrical distribution centers, etc.).

3. Base Support (BS) – Facilities and some infrastructure that are not directly tied to the execution of the primary mission, but are necessary to keep the installation/tenant functioning properly (examples include administrative facilities, supply warehouses, civil engineering shops, essential feeding centers, dormitories, etc.).
4. Community Support (CS) – Facilities that supports the installation/tenant community (examples include lodging facilities, theaters, youth centers, exchange facilities, clubs, museums, etc.) (12:10).

Each facility type or infrastructure system (i.e., electrical, water, sewer, etc.) on an installation has a particular function that supports the mission of the base. Category codes are numeric representations of those functions and are specifically spelled out in Air Force Handbook 32-1084, Civil Engineering, Facility Requirements (Sep 1996). Category codes are the basic building blocks of the ACES information management system. Each facility or infrastructure system is assigned to a category code based on the function, which then determines the appropriate FIM mission area distinctions. Buildings can change functions over time, which allows base personnel to adjust the category code and subsequent mission area if a facility function does change. These mission areas are directly related to the installation's mission, and since installations have different missions, flying operations, training, missiles, etc., various category codes may be classified differently at various installations.

> For example, at an installation with an operational flying mission, dormitories are classified as BS (mission area) facilities, but at an installation that has a training

mission, those same dormitories would be classified as PM (Air Education and Training Command).

The FIM is used to classify facility requirements within the mission areas into three mission impact ratings, critical, degraded and enhancement. These ratings are determined by the following definitions and refer to the current conditions in the facility to be addressed by the project (41:20).

- Critical – meets one of the following
    - Significant loss of installation/tenant mission capability and frequent mission interruptions
    - Work-arounds to prevent significant installation/tenant mission disruption and degradation are continually needed
    - Risk Assessment Code (RAC) or Fire Safety Deficiency Code (FSDC) of I (i.e. a RAC can be a safety requirement required by the electrical code and a FSDC can be the lack of fire sprinklers in a hospital)
- Degraded – meets one of the following
    - Limited loss of installation/tenant mission capability
    - Work-arounds to prevent limited installation/tenant mission disruption and degradation are often required
    - RAC or FSDC of II or III
- Enhancement – meets one of the following
    - Marginal or little adverse impact to installation/tenant mission capability
    - Some work-arounds may be required

- Requirements which do not meet the Critical or Degraded criteria including improvements to operational productivity, quality of life, reduction in operating costs (i.e. energy conservation)

Base civil engineers input the facility requirements (or projects) into the ACES database and recommend impact ratings based on the definitions above. Then, the installation's senior leadership (operations, logistics, communications, etc.) is encouraged to adjust the ratings through discussions until a consensus can be reached regarding impact ratings for each requirement. Installation Commanders have the final determination and are given some flexibility to adjust ratings, provided the requirement still fits within that impact rating definition. Each individual requirement in the FIM system has a particular impact rating assigned. Once Installation Commanders have approved of all requirements and impact ratings, then the requirements are rolled together for advocacy purposes at higher headquarters. A FIM integrated process team (IPT) was developed by Air Staff and includes MAJCOM representatives. The FIM IPT meets annually, since 1998, in an attempt to standardize requirement scoring and ensure credibility of the overall system, adding a check and balance step to verify Commander's ratings.

The difference between the FIM and IRR databases are a significant concern that will be evaluated in this thesis. The IRR, discussed later, also determines mission impact ratings using an entirely different method. The IRR combines requirements within a group of FACs to determine a final rating, versus the FIM, which has the flexibility of assigning individual ratings to each requirement.

The FIM is currently being reviewed for possible adjustments to better coincide with the IRR and efforts are also underway to develop a facilities restoration model (the focus of this research) by R&K Engineering contracted by the DoD. Headquarters USAF Civil Engineer (HQ/ILE) personnel are reviewing the value of adjusting the mission areas of the FIM to line up with the nine facility classes of the IRR. It is proposed that the FIM will retain the project specific mission impact ratings, but the definitions and guidance of how those ratings are assigned will have to be adjusted to reflect the change in mission areas. R&K Engineering is still in the data gathering and preliminary evaluation stage of development and a final predictive model is not expected until summer of 2003 (32).

2.4.4 Facility Recapitalization Metric (FRM)

The DoD recently approved the FRM and has instituted its use in the development of the five-year fiscal year planning document (FYDP). The FRM provides a uniform methodology for tracking investments in mainstream recapitalization programs; those programs include military construction accounts augmented by O&M and working capital funds. This methodology provides a DoD-wide solution to the problem of properly sizing investments in the recapitalization of facilities. Facilities deteriorate over time; Figure 4 indicates a typical degradation curve for an inventory of facilities. The overall curve may appear smooth, but a closer

look reveals that actual performance results in a saw-tooth shape caused by adjustments in sustainment as facilities require different levels through the years (15:5). The adequate and inadequate C-ratings indicated on the graph are discussed in the IRR

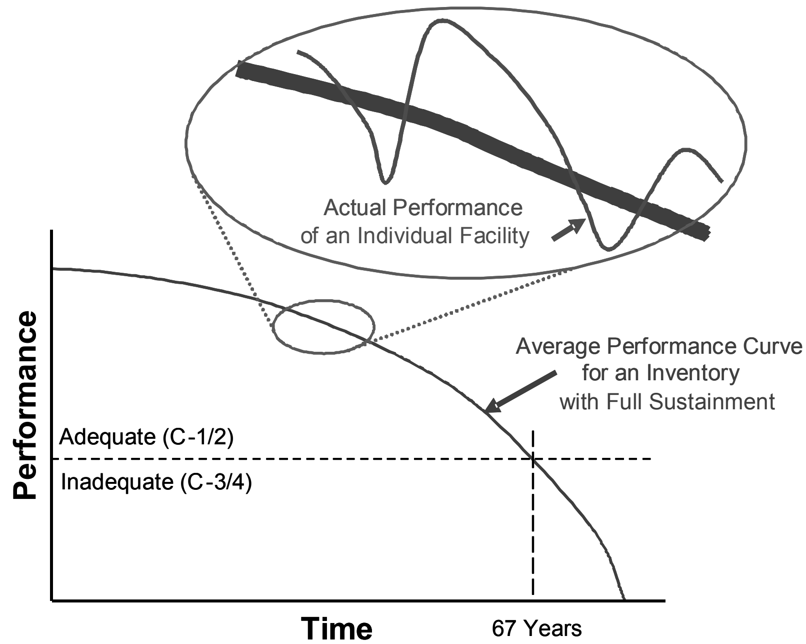


Figure 4. Facilities Performance Over Time (15:5)

section next. Even full sustainment will not change the downward slope of the curve because sustainment cannot compensate for the aging structural materials, obsolescence, mission changes, the imposition of more rigorous standards or laws, or acts of God like hail damage (15:5).

Recapitalization investments can be made to facility inventories in order to extend the expected service life of facilities beyond the DoD average of 67 yrs. Recapitalization is a combination of restoration and modernization. Restoration returns performance to original levels or, alternately, to the level defined by the normal degradation curve. Modernization, on the other hand, improves performance to a higher level above the original curve. Figure 5 indicates the impact that recapitalization can have on the degradation curve (15:6). The recapitalization rate is the number of years it would take

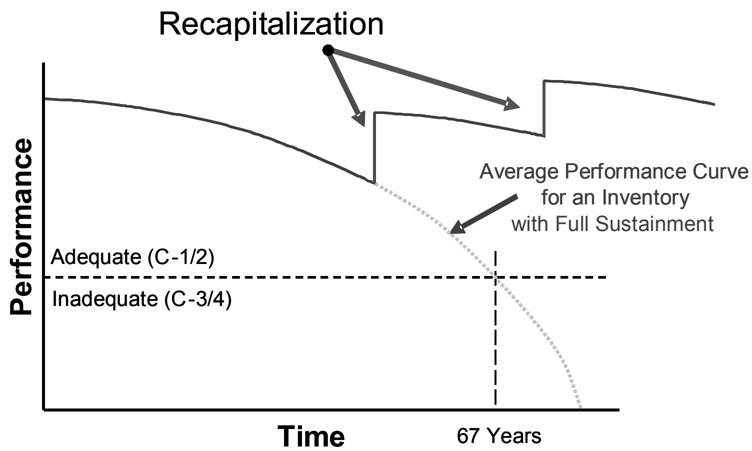


Figure 5. Facilities Restoration and Modernization (15:6)

to regenerate the physical plant, either through replacement or major renovations, at a given level of investment. The formula for the recapitalization rate is as follows:

$$\text{Recapitalization Rate} = \frac{\text{Value of Assets (plant replacement value)}}{\text{Investment}} \qquad (5)$$

> The numerator of the formula is the plant value of facilities that DoD intends to recapitalize. The denominator of the formula is the recapitalization investment programmed for the physical plant reflected in the numerator. This investment includes all funding from various funding sources (15:7).

Ideally, the recapitalization rate equals the expected service life of the assets being assessed (average DoD service life is 67 years). This is the typical inventory management technique of "rolling" replacement to keep the entire inventory operational and up to date (15:11). The FRM is not to be used in isolation however; it must be used in concert with the FSM in order to accomplish the intended purpose of maximizing useful facility service life. Unfortunately, the recent investment strategies by the DoD were insufficient to cover the sustainment level and offset the corresponding loss of service life. Once recapitalization efforts have been accomplished, those facilities still require full sustainment to meet the desired service life; without full sustainment, even the recapitalization efforts that were accomplished rapidly declined (15:6).

2.4.5 Installation Readiness Report

The AF submits the annual Installation Readiness Report (IRR) to Congress to comply with Section 117 of Title 10, United States Code. The report identifies the capabilities of AF facilities and infrastructure to support forces in the conduct of their mission (49:5). The AF portion is combined with similar reports from the other services to form the Readiness Report to Congress. This report is critical to funding advocacy and proper identification of requirements is essential. The IRR combines the data of several different reporting tools, including the FSM, FIM and other information derived from ACES-PM. The IRR divides the real property on an installation or physical plant down into nine different classes (47:2):

1. Operations and training (e.g. airfields, ranges, aircraft parking, flight simulators, missile control and launch facilities);
2. Mobility (e.g. facilities related to mobilization, staging and transportation);
3. Maintenance and production (e.g. vehicle and avionics maintenance shops, hangars);
4. Research, development, testing, and evaluation (e.g. test chambers, laboratories, research facilities);
5. Supply (e.g. warehouses, hazardous material storage, munitions storage);
6. Medical (e.g. hospitals, dental clinic);
7. Administrative (e.g. office space, computer facilities);

8. Community and housing (e.g. dining facilities, gymnasiums, child development centers, military family housing, dormitories); and
9. Utilities and ground improvements (power production and distribution, water and wastewater, roads, fuel storage, communications network)

Note: These classes are significantly different than the FIM categories.

The IRR identifies facilities that are below minimum acceptable performance standards, and also includes the estimated cost to bring those facilities back into standards. The table in Figure 5 represents the C-ratings of each FAC broken out by MAJCOM. The table is the FY 2001 summary graph and indicates that the AF had over 63 percent of its facility ratings classified below meeting minimum performance standards. This value is indicated under the "% of Ratings" section at the bottom, where 46 percent of the FACs had a C-3 rating and 17 percent of the FACs had a C-4 rating. If a facility class does not meet minimum performance standards, it is classified as a C-3 or C-4, those that meet standards are classified as C-1 and C-2.

The C-ratings are abbreviated in the bottom half of Figure 6 but are delineated further in the Table 1 and defined below. The C-ratings are derived by adding up all of the requirements in the facility classes and then dividing that total by the total PRV of that FAC in each MAJCOM. If the percentage is less than 10 percent, the facility class receives a C-1 rating (see Figure 6); if the percentage is between 10 and 20 percent, the facility class receives a C-2 rating; if the percentage is between 20 and 40 percent, the facility class receives a C-3 rating; and if the percentage exceeds 40 percent, the facility class receives a C-4 rating.

	FACILITY CLASSES								
	OPS & TRAINING	MOBILITY	MAINT & PROD	RDT&E	SUPPLY	MEDICAL	ADMIN	CMTY SPT & HSG	UTILITIES & GRNDS
BY MAJCOM or MAJOR CLAIMANT (as of 1 Feb 02)									
ACC	C-3	C-3	C-3	C-1	C-3	C-2	C-3	C-4	C-2
AETC	C-3	C-3	C-3	C-1	C-2	C-1	C-2	C-4	C-3
AFMC	C-3	C-2	C-3	C-3	C-3	C-2	C-3	C-3	C-3
AFRC	C-3	C-3	C-3	N/A	C-2	N/A	C-2	C-4	C-3
AFSOC	C-4	C-1	C-2	C-1	C-3	C-4	C-4	C-3	C-1
AFSPC	C-2	C-2	C-2	C-1	C-2	C-3	C-3	C-3	C-2
AMC	C-4	C-4	C-3	N/A	C-3	C-2	C-4	C-3	C-4
ANG	C-3	N/A	C-3	N/A	C-3	N/A	C-2	C-3	C-2
PACAF	C-3	C-3	C-3	C-1	C-3	C-1	C-4	C-4	C-3
USAFA	C-3	N/A	C-1	C-1	C-1	C-3	C-3	C-2	C-3
USAFE	C-3	C-4	C-4	N/A	C-4	C-2	C-3	C-4	C-3
11 ABW	C-1	N/A	C-3	N/A	C-2	C-1	C-2	C-4	C-2

% of Ratings		
14%	C-1	Only minor deficiencies with negligible impact on capability to perform required missions.
23%	C-2	Some deficiencies with limited impact on capability to perform required mission.
46%	C-3	Significant deficiencies that prevent it from performing some missions.
17%	C-4	Major deficiencies that preclude satisfactory mission accomplishment.
	N/A	Not applicable: do not have category codes or real property in this area.

Figure 6. FY 2001 USAF IRR C-Ratings by MAJCOM and Facility Class (49:7)

Table 1. C-Rating breakout compared with PRV (47:8)

C-Rating	PRV% Range*
C-1	0 to 10%
C-2	>10% to 20%
C-3	>20% to 40%
C-4	>40%

* The PRV range is the total facility requirements within that facility class divided by the total PRV of that facility class

The IRR has four different classifications for the facilities' ability to meet mission requirements as indicated by the different shades in Figure 5 (47:3):

1. C-1 - Only minor deficiencies with negligible impact on capability to perform required missions. As noted in Figure 5, the FY 2001 IRR data indicate that 14 percent of facilities and infrastructure in the Air Force are in the C-1 classification.

2. C-2 - Some deficiencies with limited impact on capability to perform required missions. FY 2001, IRR data indicate that 23 percent of facilities and infrastructure in the Air Force are in this classification.
3. C-3 - Significant deficiencies that prevent performing some missions. FY 2001 IRR data indicate that 46 percent of facilities and infrastructure in the Air Force are in this classification.
4. C-4 - Major deficiencies that preclude satisfactory mission accomplishment. FY 2001 IRR data indicate that 17 percent of facilities and infrastructure in the Air Force are in this classification.

The total of C-3 and C-4 requirements indicates that over 63 percent of facility ratings in the AF are indicating that those facilities are not capable of adequately supporting mission requirements without significant workaround or mitigating measures.

The C-ratings are determined from mathematical equations that divide the total weighted requirements (TWR) by the applicable bases' PRV to obtain a percentage for each facility class (47:8), Equation 6. The C-rating does not take into account the mission impact of a particular facility requirement, rather the aggregate score for the entire facility class. The TWR is a compilation of all requirements within a particular facility class. The restoration and modernization requirements are broken down into three categories (this is the TWR indicated in Equation 6 as the numerator) that measure mission impact: critical requirements (CR) are weighted the most heavily (five times the requirements value), degraded requirements (DR) are given a moderate weighting (three times the requirements value), and enhancement requirements (ER) are not weighted (no multiplier).

$$\text{C-Rating} = \frac{(CR \times 5) + (DR \times 3) + (ER)}{PRV} \quad (6)$$

where CR is critical requirements, DR is degraded requirements, ER is enhancement requirements (these three make up the TWR), and PRV is plant replacement value.

All restoration and modernization requirements are combined with the sustainment requirements to create the TWR value as well as the PRV for those facilities. The example below explains the calculation process.

Consider ten restoration projects valued at \$2.6 million identified for six facilities within the mobility category at a particular AF base (1 of 9 explained earlier) (PRV of the facility class is \$32.6 million); two projects are determined to be critical with a total estimated cost of \$1.1 million, four projects are determined to be degraded with a total estimated cost of \$1 million, and the remaining four projects are enhancement, substituting these values into Equation 6 above:

$$\text{C-Rating} = \frac{(\$1.1M \times 5) + (\$1M \times 3) + (\$.5M)}{\$32.6M}$$

$$\text{C-Rating} = .28, \text{ or } 28\%$$

The mobility facility class for this base would receive a C-3 rating (by using Figure 6) and would not meet minimum performance standards.

The IRR C-ratings can be calculated at any level, installation, MAJCOM, or AF level, depending on the decision maker requesting the information. As the requirements are summed up at the MAJCOM and AF levels, the installations with adequate (C-1 and C-2) facility class ratings will dilute some of the installations with inadequate (C-3 and

C-4) ratings and vice versa. This sum total value makes it difficult for decision makers to determine the true readiness state at each installation; rather it is an aggregate wrap-up of the entire AF facility inventory. The IRR is a good tool to articulate the overall state of installation readiness, but lacks the detail to really deal with the situation once the decision makers appropriate funding to correct the requirements. This research will attempt to identify possible adjustments to the FIM and IRR to increase the integration of the tools and identify ways that they can better articulate the requirements to decision makers.

Overall, the AF has structured a plan, using ACES, FSM, FIM, together with the IRR, to correct facility deficiencies and bring the facilities that are below standards back into standards and keep the good facilities properly maintained for their entire life cycle (49:26). This plan maximizes the strengths of each system and tool in articulating the information in such a way that decision makers can readily understand the total facility requirements and the mission impact if those requirements are not corrected. Recommended adjustments to encourage integrations of these tools will assist decision makers in advocating this strategic plan.

III. METHODOLOGY

This chapter explains the methodology that corresponds with the objectives of this research. The chapter is divided into three main sections: background on model development, building a model, and improving integration. The first section defines the background of model development and explores the different methodologies that were researched and molded into the methodology explained in the next section, building a model. The model building section breaks out the different steps used in this research. The final section describes the evaluation of the different tools that use a complex system investigation to determine ways to improve integration in the facility management process used by the AF.

3.1 Background on Model Development

This section builds on the different methodologies that are referenced in this research, Chapter 2, as well as the basic premises used for estimating facility costs. These different methodologies were analyzed, adjusted, and combined to create the hybrid methodology discussed in the next section. Understanding the existing methodologies used for facility management was instrumental in developing a new approach.

Facility managers from both private sector and government organizations experience hard decisions every day. For example, they must decide what critical repair should they accomplish first with the limited resources at their disposal. Typically, decisions are usually difficult because of their complexity. Decision analysis provides effective methods for organizing complex problems into a structure that can be analyzed with more accuracy (6:2). The formula based methodologies discussed below use decision analysis techniques to develop the predictive models to make decisions on how much funding is required for facility maintenance. Difficult decisions can often be broken down into smaller elements that are simpler to evaluate and these components can be analyzed separately. The components can be reorganized into an understandable combination that covers the entire complexity of the decision. Use of decision analysis methodology and techniques can lead to better decisions.

One of the significant decisions faced by facility managers is predicting future sustainment (operating and maintenance) expenses in a logical and defendable manner. This activity may result in a properly maintained physical plant, or if it fails, will result in infrastructure decay and more costly repairs in the future when systems fail because of poor sustainment. It is very important that facility mangers establish a balance that provides full sustainment, but does not inadvertently waste resources as well. Although very accurate estimates are often difficult, historical analysis of sustainment costs, along with studying the factors that contribute to those costs, can greatly improve the accuracy in making predictions (5:52). The prediction methods outlined in Chapter 2 continue to evolve as more cost factors are documented and can be used for analysis.

When full sustainment is not accomplished over a period of time, it often requires some restoration to return the facilities to an acceptable level of performance. The formula budgeting methodology that was introduced in Chapter 2 is the focus and premise of the model proposed in this research. This methodology results in a clear and understandable estimate of the total facility restoration requirement and is easy to articulate and justify to decision makers. Also, the AF maintains an extensive database of information that lends itself to in-depth analysis using the formula budgeting methodology. Numerous formula-based estimating models have been developed in recent decades and have used similar basic steps in establishing the models. All of the formula based predictive models were developed to estimate a particular variable, like expected maintenance costs, which hereafter will be referred to as the response variable. The variables used in the formula to determine the response variables are called predictor variables.

Three different research models will be discussed; they are the methodologies developed by Nealy and Neathammer (34), Christian and Pandeya (5), and Hutson and Biedenweg (26). All three research efforts developed a formula based approach, described in Chapter 2, to estimate facility requirements. The researchers approached the same area of interest, facility sustainment, using slightly different methodologies, but each with a consistent goal of developing a formula based model that is relatively simple to use and can be applied to almost any size of physical plant.

Nealy and Neathammer (34) developed a formula based approach to estimate facility sustainment requirements using a database of facility information and uses. The step by step methodology, illustrated in Figure 7, used for their research was: 1) development of a database of facility sustainment requirements, 2) focus on the variable of predicting annual facility sustainment costs, 3) determine the high-cost variables that were the most significant in building sustainment, 4) build database that included the averages of the cost variables, 5) build a funding projection model using the cost variables, and 6) estimated facility sustainment cost and advocated for funding using justifiable reports and calculations versus expert opinion. This research was funding by the Army to develop a predictive model to determine facility sustainment costs from an extensive database of information. Their research helped justify the importance of maintaining a complete database of facility information and maintenance records and the relationship that these variables have in predicting future requirements.

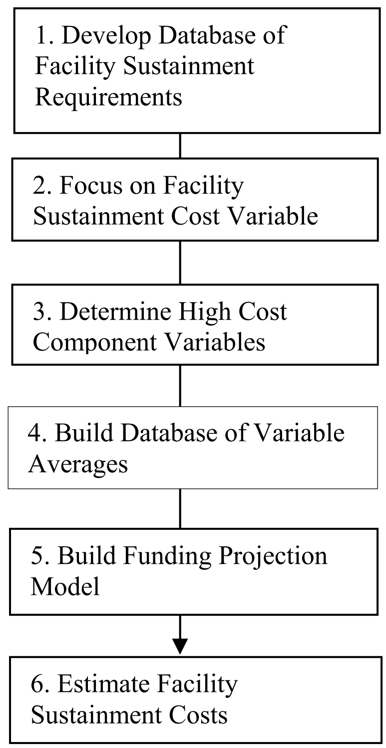


Figure 7. Methodology used by Nealy and Neathammer (34)

Christian and Pandeya (5) used a slightly different approach, focusing on facility manager's expertise to develop an expert system capable of predicting long-term maintenance costs, space projections, maintenance planning, and energy conservation suggestions. They consolidated the process down into four steps (see Figure 8), 1) determination of factors, 2) data collection, 3) knowledge elicitation, and 4) data analysis and prediction. They began by defining what the database should contain and then began to populate the database by eliciting information from subject matter experts (SME).

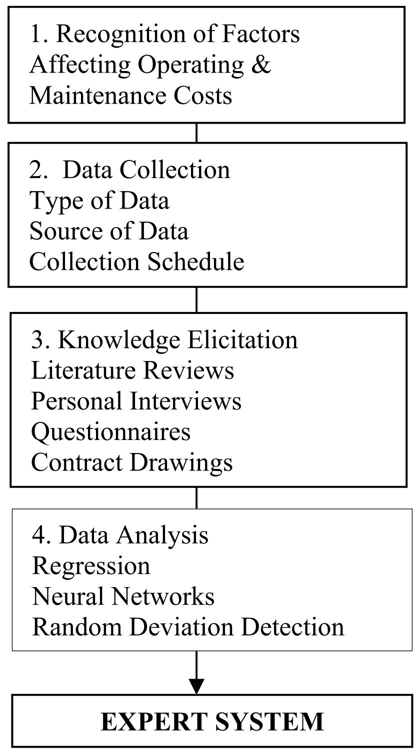


Figure 8. Methodology used by Christian & Pandeya (5)

They employed SMEs during the knowledge elicitation (step 3) in determining predictions and forecasts of building system maintenance requirements to do their analysis and come up with an overall facility maintenance estimation model. Their research focused on the importance of the cost predictors, or predictor variables. They used a survey tool to elicit and populate their facility database with information provided by facility managers. The survey was an extensive questionnaire that had the facility managers identify every detail of their facility inventory, items like: height of facility, exterior wall construction, roof construction material, types of light fixtures, etc. This method allowed them to track only the predictor variables that they, and especially the subject matter experts, felt would contribute to the accuracy of the prediction estimates. The survey was paired down during each iteration until only the most significant variables remained. They used statistical linear regression analysis to identify the significant predictor variables that constituted the greatest causal relationship with the response variable, facility maintenance costs. As an example, they used the years (1970-1996) as the independent variable (x-axis) and the O&M costs each year as the dependant variable (y-axis). The regression analysis for just that one predictor variable (year) returned a coefficient of determination (R-square) of 0.83, which indicates a significant causal relationship. Although they determined that a non-linear curve had a higher R-square of 0.92, they avoided this method because of the unrealistic cost-time profiles (5:58). The significance of this work indicated the applicability of statistical regression analysis in building of the model to estimate facility requirements, which is the basis for this research.

Hutson and Biedenweg (26) used a combination of historical line estimating, physical survey, and formula based approach in developing a predictive model to estimate physical plant renewal costs, similar to recapitalization cost. In developing their model, they used a four step process, 1) develop a conceptual framework (database and predictors), 2) establish framework to model (simulate replacement costs), 3) inspect the results (actual site investigation to confirm estimates), and 4) sensitivity analysis (use the optimistic and pessimistic estimates to determine the range to ensure actual results were within range). Their research developed a quantitative method that programmatically addressed the short and long-term physical plant needs (26:13). Step 1 involved extensive research and manipulation of data. After reviewing historical physical records for

Stanford University's physical plant, they noticed a cyclical pattern of facility costs, indicating that the university had built its building in cycles. They smoothed out the peaks and valleys of the cyclical pattern by spreading the replacement costs of substantial system over five to ten year periods versus the two-year periods experienced prior. This analysis required a complete inspection of building components to determine their current condition, expected life, and possible replacement costs. They combined this detailed facility database with a formula based approach to create a mathematical model (Step 2). The model simulated actual conditions at a specific location, providing very detailed and defendable estimates to decision makers (Step 3) (26:29). The final step was a sensitivity analysis to determine which factors warranted special attention and would become the focus of the facility manager's attention. This methodology broadens the scope of normal formula based approaches to consider actual present day conditions of system components. Unfortunately, this method is labor intensive and often not economical for organizations with a large facility inventory.

The methodologies used by these researchers in developing their estimating models are different, yet have some common threads. All of them started with the development of an extensive database of facility information, then focused on the variables that were most significant, and developed a predictive model to estimate facility sustainment costs. The methodologies used in these prior research efforts were broken down to determine which concepts were appropriate for this research that focuses on restoration requirements versus sustainment requirements, and evolved into a hybrid methodology that best fit this scenario.

The literature also indicated some basic premises regarding predictive models for estimating facility costs. In order to be used, a predictive model for estimated facility costs must be responsive to two distinctly different sets of factors; those relating to the facilities themselves; and those related to the political arena in which facility restoration funding takes place (43:21). The factors relating to the facilities are included in the data set identified in above methodologies, but the political factors must also be considered in the methodology. The AF level decision makers are concerned with macro level issues and need a model that is generally applicable, simple to apply, easy to understand, self-adjusting, and reliable. Combining the different approaches used in the preceding research, along with these basic premises, this research developed a hybrid approach identified in the next section.

3.2 Building a Model

This section explains the rationale used to develop the hybrid methodology for predictive model building used in this research. Taking the methodologies employed by researchers in the facility maintenance field, this research developed a slightly adjusted methodology that combines different aspects of existing methodologies into an alternate logical procession of steps. Figure 10 depicts the model. First, each step is summarized to provide an overview of the model, then each step is discussed in depth.

The methodologies identified in the previous section have several key components in common. They all started by developing some type of database (Step 1) that incorporated the specifics about the facility and infrastructure systems under evaluation. Collection of data, though, is just the foundation from which to conduct an

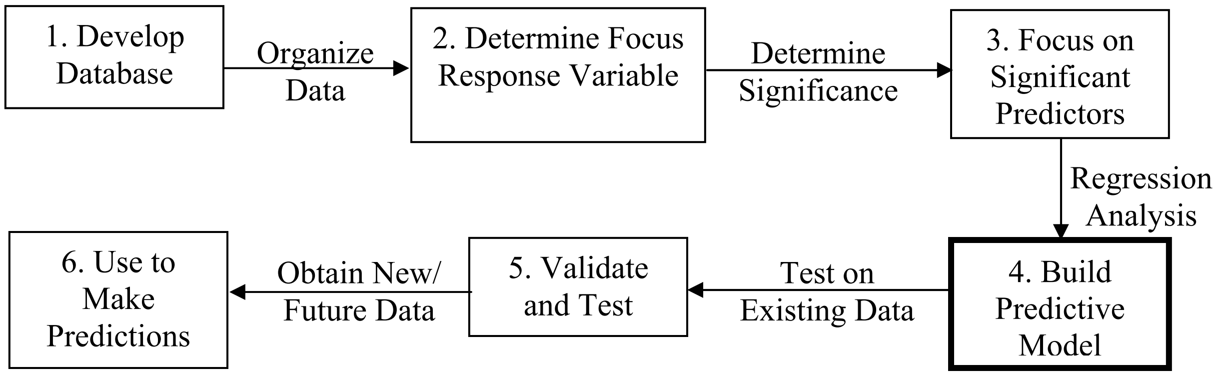


Figure 9. Model Building Process

analysis. Once the data is compiled, the next logical step is to organize and filter the data into a manner that can be easily analyzed. This step was specifically identified by Nealy and Neathammer (34), but only marginally addressed by the other two methods. This provides insight and helps the researcher determine what variable of interest they would like to estimate (Step 2). Databases can contain an enormous amount of different variables, but not all variables are significant or provide any value to the decision making policies. All of the previous research conducted some type of preliminary analysis to narrow the scope of variables that were considered. Some variables, like facility number, only aid the system in tracking requirements and do not provide any contribution to estimating the facility costs. Therefore, the preliminary analysis will determine the significance of the variables and allow the research to focus on the significant predictors that contribute the most causal relationship with the response variable (Step 3).

Once the data is thoroughly filtered and analyzed, the next sequential step is to run the variables through a statistical regression analysis and build the formula based model (Step 4). Nealy and Neathammer (34), and Hutson and Biedenweg (26), identified model building as a specific step, while Christian and Pandeya (5) combined many activities in their final step of data analysis and prediction. Once the predictive model is built, it must be tested and validated to ensure that it is robust and accurate. All of the methodologies conduct this step, but do not necessarily delineate it as a separate step. Most of the researchers separate out a portion of the database out to use during the testing and validation step. Since this is historical data, the sustainment costs are known, thereby allowing the formula model to be tested to ensure that the estimated costs derived from the model are close to if not identical to the actual recorded costs. Hutson and Biedenweg (26) conducted this testing and validation step through sensitivity analysis which varied the subsystem expected service life using a beta distribution of mostly likely, optimistic, and pessimistic service life. These variations proved that the most likely and optimistic distribution forecasts were very similar and dominant, which validated their overall model.

Finally, the last step is logically to use the model for the intended purpose, prediction (Step 6). Since historic data was used to develop the model, it makes logical sense to extract current data from the database to be used for this purpose, providing real time facility specific information. Providing a facility manager with a predictive model will equip them with a justifiable and repeatable methodology for articulating facility requirements to decision makers. Depending on the size of the physical plant, this methodology can also be used to allocate appropriated resources to a significantly large physical plant spread over numerous locations, as in the case of the AF.

3.2.1 Step 1 - Develop Database

A physical plant database must include extensive data regarding the physical plant and also have several characteristics to ensure that the data can be evaluated. Chapter 2 identified several examples of these databases, including the CMMS systems employed by many private industry organizations, as well as the ACES database employed by the AF. The data contained in the database must be relevant, current, and as correct as humanly possible (29:28). The data must be appropriate to the focus response variable identified in the next step. The format of the database must be such that the data can be easily extracted into reports for analysis. If several databases are in use and not connected, then organizing the data and conducting an analysis is difficult and often the manpower required is not cost effective. If the data is current and easily extracted, estimators will be able to develop the model with relative ease and accuracy (30:208). Also, in order to develop a predictive model, the database is usually historic in nature and may date back several years.

For this research, the FIM data, which encompasses all annual facility restoration and modernization requirements in the AF, was provided, as well as the real property data (PRV), both extracted from the AF ACES database. Five years, 1997-2001, of FIM historical data was analyzed during the process. The PRV dataset that contained all the real property related information was a single data extraction done in FY 2000. Each of the databases is described in depth in Chapter 4 during the analysis stage.

3.2.2 Step 2 - Determine Focus Response Variable

This step identifies the response variable that a researcher is trying to estimate. The focus response variable is the variable that predictive model is trying to estimate.

There has already been significant research that has centered on the facility requirement variable or facility maintenance costs (5) (29) (34) (37). These research efforts, discussed in Section 3.1, provided facility managers with tools to accurately estimate and articulate facility sustainment requirements to decision makers. Different models focus on different things; the focus response variable for this research is facility restoration costs. This variable is loosely determined in the estimating process used today in the AF and this research could result in improving that process. Determining the focus response variable for this research was a simple step, however, the overall methodology should include this initial step for any future research effort.

Overall, the response variable of choice should clearly answer or address the focus area of interest. In this research, that focus area is facility restoration costs. The AF has an established method for predicting maintenance or sustainment costs in the FSM. However, the AF does not have a clearly defined method for predicting restoration costs.

3.2.3 Step 3 - Focus on Significant Predictors

This step narrows the field of possible predictor variables to only those variables that significantly contribute to the determination of the response variable. Predictor variables are those used in the model formula to determine the response variable. The datasets that are available often contain variables that are descriptive and supply no relevant information to estimating facility restoration costs. By eliminating these non-relevant variables during this step, the research can then focus on the variables that may provide some causal relationship with the focus response variable. Estimates for a response variable identified in the previous section are based on these causal relationships with predictor variables.

From the literature review, the predictor variables expected to have a significant relationship with facility restoration requirements will be: the size of a facility or infrastructure, the age, the construction type, the maintenance record, the manufacturer's recommended replacement period, the usage, and the climate of the area (26:15; 37:37; 5:52). The size of the facility provides a simple relationship and will affect maintenance costs on a linear scale. Construction type, on the other hand, has a complex relationship with the response variable which can vary significantly in type as well as quality. Although the research indicates that these may be the most significant, analysis on other predictors will be accomplished to validate that they either should be eliminated or considered.

Other available predictors in the FIM dataset include the project number and other fields defining different MAJCOM information; perhaps one of the MAJCOM variables may prove important because different MAJCOMs provide their installations with varying levels of funding. The plant replacement dataset includes predictor variables like initial construction cost, replacement value, and real property maintenance funding provided during the life of the facility. These significant predictor variables will be evaluated in the next step as the model is developed.

3.2.4 Step 4 - Build Predictive Model

This step involves the analysis of the database and development of a statistical linear regression model. This step establishes the balance between incorporating too many predictor variables, which can be very costly to accumulate and manage, and selecting just enough variables to accurately estimate the response variable. Each significant predictor variable contributes to reducing the estimation error of the response variable. The key to this step is determining which predictor variables contribute the most to reducing that error and how they interact with each other. In some cases, when predictor variables are combined, they reduce the estimation error more significantly than they did independently; however, that is not always the case.

A systematic step-wise comparison using a statistical software package, JMP V4, will evaluate each predictor variable contribution, as well as interactions between predictors to determine the proper order of significance. JMP was used because it is applicable, easy to use, has quality graphics, and was available. Interpretation of the statistical results is critical in determining which factors to choose since using all factors is redundant and difficult to organize. Simple linear regression is an appropriate and justifiable process for analyzing these relationships, as indicated in Chapter 2. The significant predictors available in the data set under investigation will surface during the analysis and can be included into the overall model.

The model that is developed must conform to the following political factors: 1) it must be logical, the estimates must reasonable, and provable by calculations from measurable data; 2) it should be convenient, the estimates must be rapidly calculated and updated once the database is established and correct; lastly, 3) the model must be understandable, the arithmetic must be easy to explain (37:43). Once the model is produced, the next step is justifying its credibility to decision makers.

3.2.5 Step 5 - Validate and Test the Model

This step will test the model by taking an existing set of data, set aside for testing purposes, and run it through the model to validate the accuracy of the estimates with a given outcome already known. The data should be a subset of the overall data set to lend credibility that the model captures the integrity of the data set. Since this is historical data, the actual total for restoration requirements each year is known and can be used to validate the model. The data will be used in the model and the model's estimation will be compared to the actual results from the historical data. If the results are within a confidence interval of ± 5 percent, then the model will be considered reliable and valid. For this research, five years of FIM data are available; one year of data will be set aside for testing and validation.

3.2.6 Step 6 - Use to Make Predictions

The overall purpose of this research and the other research in this field is to accurately predict facility requirements within a particular confidence level. Using FY 2002 plant replacement data, this research will try to predict restoration requirements at the installation level. These estimated restoration levels may assist MAJCOM programmers in allocating available funding for FY 2003. Since current funding levels are not high enough to meet the total estimated restoration costs, the FY 2003 predictions using the FY 2002 plant replacement data may assist programmers in articulating requirements to decision makers. This may provide the needed justification for increases in funding levels at the HQ Air Force level.

3.3 Improve Integration

The third objective of this research is to improve the integration of the different advocacy tools used by the Air Force. This objective involves the evaluation of a complex system. The simplistic diagram in Figure 10 indicates the complex system for this research and how the different systems and tools relate. The overall process begins with the ACES database, providing all of the raw data that is interpreted by the different tools in different manners. The FSM, FIM, and FRM, identified in Chapter 2, extract data directly from the ACES database and provide reports based on that data. These reports are used to advocate for facility funding. The IRR takes data from ACES, but also incorporates different elements from the FSM and FIM.

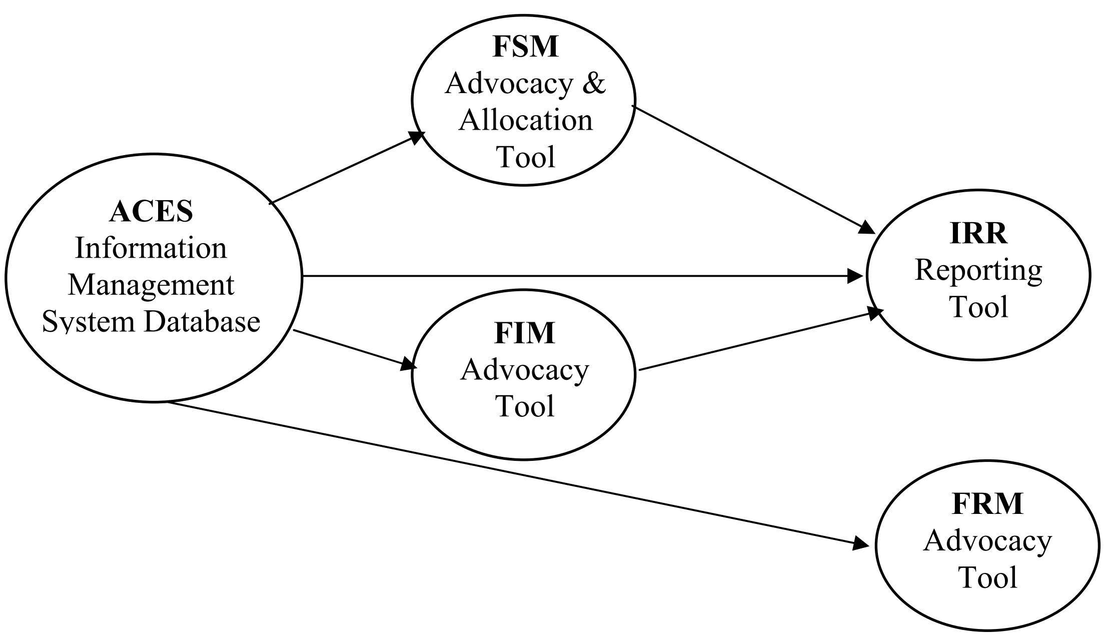


Figure 10. AF Facility Management Process

3.3.1 Approach to Complex System Evaluation

This research will follow the flow of a particular set of requirements from the database to the reporting tools, identifying how each tool interprets the data and uses the data in the overall process. This approach was appropriate for this research because it broke down each component of the overall system and the inter-relationships within, thus exposing where the components can be better integrated. This complex system evaluation will identify the key differences between the tools and will also clarify the important aspects that each tool provides to decision makers. With this information, the evaluation process will help identify integration opportunities and adjustments that may be made to the tools to better inform decision makers and make the tools more understandable and credible.

IV. RESEARCH RESULTS

This chapter explains in detail the steps taken to complete this research. It will expand upon the literature search and then go directly into the methodology steps taken to derive the predictive model to estimate facility restoration requirements. There were two databases used in this research, the FIM and PRV databases, which will be explained in detail later in this chapter. The hybrid methodology uses a six-step model building method that begins (Step 1) with the development or acquisition of a database. Step 2 identifies which variable will be the focus response variable, the variable that the predictive model is trying to estimate. Step 3 identifies the two databases that were used and the many predictor variables that the researcher had to choose from to narrow the field to something that was manageable. Step 4 actually builds the model through stepwise statistical regression analysis. Step 5 runs the predictive model through a series of validation and testing scenarios to ensure that the model is accurate. Step 6 tries to apply the model in a real world scenario of predicting restoration funding requirements for a particular AF installation. Finally, the chapter explores the results of the complex system evaluation of identifying and articulating facility requirements to decision makers using the various tools described in this research, the FSM, FIM, FRM, and IRR, and also identifies integration opportunities and adjustments.

4.1 Literature Search and Acquisition of Data

The literature search revealed several predictive models that are being used today for estimating facility maintenance (sustainment) requirements. These models are not specific to the Air Force infrastructure, but the literature did identify which predictors or variables regarding facility restoration requirements may be most significant. Given these recommendations, specific AF data regarding facility restoration requirements (FIM) was acquired from HQ USAF/ILER. The FIM was divided into five datasets, FIM I through FIM V. The datasets represent snapshots in time of all the facility requirements in the AF at the end of each fiscal year from 1997 to 2001 taken from the IWIMS and ACES databases. As indicated in Chapter 2, the FIM is used at the macro AF level to define total facility restoration and modernization requirements to decision makers. Therefore, the data that is extracted from ACES to develop the FIM is the information that are of pertinent interest in order to identify total facility requirements and do not include much of the facility related variables needed for the analysis conducted under this research. As a result, HQ AFMC/CEPD provided a dataset regarding the physical plant characteristics of all the facilities and infrastructure in the AF, the plant replacement value (PRV) dataset. This dataset is enormous in size, including every facility and infrastructure system at every AF installation in the world. Only through the combination of the two datasets was the research analysis even possible. Each database contained thousands of pieces of data, representing over a hundred different variables. However, as indicated in the next sections, the two databases were not perfectly matched all of the time and the challenges are explained later as each of the six-step process is laid out.

4.2 Step 1 – Develop Database

This section identifies the databases used during this research and the manipulation of the databases into a single format that could be analyzed. The data supplied by HQ USAF/ILER and HQ AFMC/CE incorporated five years of FIM restoration requirements, 1997-2001 for the analysis and a snapshot of the plant replacement data current as of FY 2000. The data was in a mixture of computer formats. The FIM datasets contained all FIM requirements for the AF, which included some sustainment (only FIM I), but mostly restoration and modernization requirements. The focus of this research was concerned with only the restoration requirements and these requirements needed to be extracted from the FIM dataset, eliminating the rest of the requirements.

This filtering was accomplished by sorting the dataset in a number of ways. The FIM dataset came in two formats; the FIM dataset (19) for FY 1997 (FIM I) came in Microsoft Access format, while the rest of the FIM datasets (20; 21; 22; 23), FY 1998-2001, were in Microsoft Excel. As a result, the FY 1998-2001 (FIM II-V) Excel datasets were transferred into Access to consolidate all the data into a single format, Access. The transfer was accomplished by opening up the Excel files in Access as "New Tables" and converting the data. Access runs through several setup screens, but the transfer is simple and the end results looks identical to the way the data looked when in Excel.

4.3 Step 2 – Determine Focus Response Variable

The focus response variable for this research was restoration cost, however, in the FIM datasets, this variable is actually termed "Programmed Amount" (PA). This amount is the estimated cost for facility requirements, broken out by individual projects in a facility. Sometimes, there is only a single facility project requirement and subsequent PA, but for large facilities or infrastructure systems, there are sometimes numerous facility project requirements, each with a separate PA. The PA represents a preliminary cost estimate for the facility requirements as defined by the facility manager, but the project has not entered the design phase and the indicated cost is just a best-guess estimate on the part of the installation programmer. Often, the installation programmers use square foot cost guides to estimate facility renovation requirements or they consult different cost estimating guides to develop the PA, all of which provides the FIM with a rough order estimate that can be combined in the FIM matrix and forwarded to decision makers to aid in advocating for funding.

4.4 Step 3 – Focus on Significant Predictors

This section identifies the numerous predictor variables used during this research and the methods used to filter the datasets into a manageable arrangement of significant predictors. The PRV dataset was a snapshot in time of all the real property in the AF taken in the summer of 2000 (39). The PRV dataset is extensive, including just about every descriptive facility and installation variable imaginable, and needed to be pared down to a more manageable size as explained in the next section. Consulting a subject matter expert, Mr. Wayne Miller from HQ USAF/ILE (33:1), he indicated which variables that he felt may have some relevance to this research and which to exclude because they either were not inputted for all facilities, or were just tracking variables for use by real property professionals. The section below identifies the steps taken to filter the data out of the PRV database in the most accurate manner possible.

The FIM datasets presented a challenge because they did not all contain the same information to be used for analysis. The FIM datasets contained project specific variables and other variables necessary for higher headquarters analysis, all of which were not relevant to this research. Also, the FIM datasets, although they contained numerous similar variables, also contained different variations of predictor variables (some were more detailed than others). The FIM I, IV, and V datasets were the most complete and simplest to filter the data. The FIM II dataset did not include the classification code for the type of work (EEIC, to be explained in the next section), which identifies if a project requirement is a sustainment, restoration, modernization, demolition, etc., facility requirement. The following subsections identify how each FIM dataset was filtered down to what was considered the most significant response variables.

4.4.1 Plant Replacement Value (FY 2000) Dataset

The PRV dataset was pared to a manageable dataset for this research. The PRV dataset was supplied by HQ AFMC/CEPD and contained very specific facility information for every facility in the AF inventory; there were 229,679 facility entries in the PRV database. The PRV dataset contained 122 types of data entries (for a total list of variables, see Appendix A). These main data entries represent was has been termed possible "predictor variables" in this research and will be used interchangeable from hereafter. Figure 11 is screenshot of the database taken from the Microsoft Access database. Figure 11 provides a sample of some of the variables (column headers), but only 10 of the 122 possible predictor variables (columns) and only 25 of the over 220,000 facilities (rows) in the database are visible.

The number of possible variables (columns) in the PRV dataset was too large to work with so variables that were deemed not necessary were systematically eliminated. There were numerous reasons why variables were eliminated. As displayed by Figure 11, some columns contained no data (cells that are blank like the rows under the column Bedrooms). There were over 30 variables that fell into this category and were therefore eliminated. Over 20 of the variables (columns) consistently had a value of "0" in the

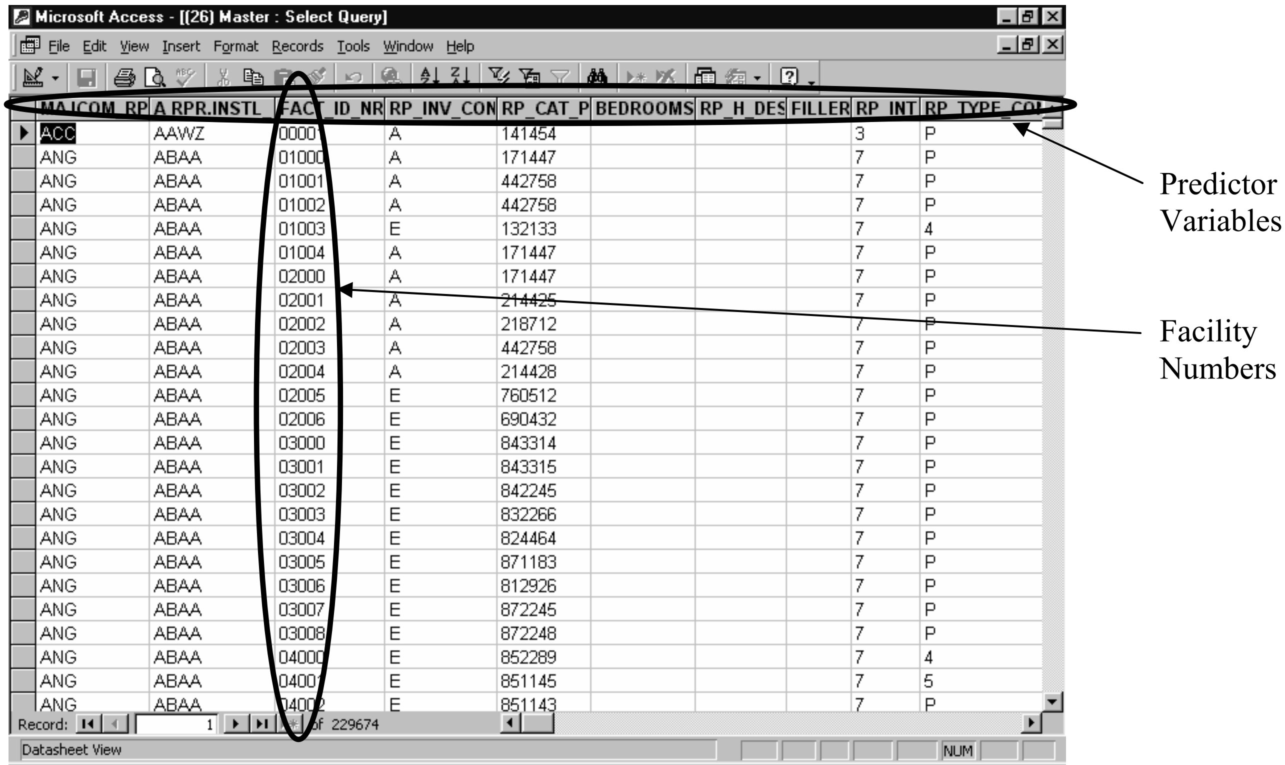


Figure 11. Screenshot of the Plant Replacement Value Database

corresponding facility row, indicating no real value to this analysis, so those too were eliminated. Several other variables were present for specific classes of facilities, like MFH (military family housing) and QoL (quality of life) variables, but not for all facilities. These variables were eliminated because the variables that are used should consistently have a value. If only certain facility classes have values for a particular variable and the rest do not, then the significance of that variable is skewed and will corrupt the resulting analysis.

The predictor variables for the "INSTL LOC INDCTR" (installation code) and the "FACT ID NR" (facility number) variables are the two required to link the PRV dataset and the FIM datasets. Those two variables are identical in the two respective databases and by linking those two variables in Microsoft Access, all of the facility specific information in the PRV dataset can be combined with the facility requirement information in the FIM datasets.

After sorting and eliminating over half of the possible data entries (variables), the real property dataset (PRV) was down to about 50 variables. The remaining variables were considered of interest to this research and a simplified dataset was created with just those variables (to be combined with the FIM datasets). By filtering the overall PRV dataset down to a more manageable 50 variables, the processing time for the analysis was quicker and the opportunity for Access to pick up redundant entries is significantly less. The 50 variables are included in Table 2; the "Database Abbreviation" columns include the actual titles as seen in the database (see Figure 11). The "Actual Title" columns provide a more descriptive and understandable version for the variables.

Table 2. PRV Predictor Variables - Reduced Dataset

Database Abbreviation	Actual Title	Database Abbreviation	Actual Title
1. INST LOC INDCTR	Installation Location Indicator	2. INSTL NAME 40	Installation Name
3. FACT ID NR	Facility Number	4. RP INV CON	Real Property Inventory Control Variable
5. MAJCOM RP JRSDCTN	MAJCOM with Real Property Jurisdiction	6.RP CAT PRES	Real Property Category Code
7. RP INT	Real Property Investment Code	8. RP TYPE CONSTR	Real Property Type Construction Code
9. RP COND	Real Property Condition Code	10. RP AREA AMT	Real Property Area Amount
11. MONETARY VALUE RP	Monetary Value of Rent Paid	12. MONETARY VALUE RR	Monetary Value of Rent Received
13. COST GOV	Initial Cost to the Government plus Improvements	14. CURR INSTL LOC NAME	Current Installation Location Code
15. CURR INSTL LOC KIND	Current Installation Location Type	16. STATE ENTRY ABBREV	State Abbreviation
17. STATE CNTRY CODE	State/Country Code	18. NRST TWN CITY	Nearest Town or City
19. MAJCOM RP JRSDCTN 3	MAJCOM with Real Property Jurisdiction Code	20. AREA UOM	Unit of measure for the Real Property Area
21. OTHER UOM	Other unit of measure	22. YR COMP	Year Initial Construction Complete

Database Abbreviation	Actual Title	Database Abbreviation	Actual Title
23. DOD GROUP CODE	DoD Group Code	24. CY ACT	Calendar Year Activated
25. INSTL FUNCT	Installation Function Code	26. TYPE INSTL REAL PRPTY	Type of Installation Real Property
27. USAGE CODE	Usage Code	28. INSTL INDCT PAR	Installation Indicator Parameter
29. RP RPLCMNT	Replacement Cost in $000	30. Majcom Credit	MAJCOM that gets the Credit for this facility
31. PRV 97	FY 00 Plant Replacement Value	32. PRV 97 OPEN	FY 00 Plant Replacement Value Open
33. PRV 97 MILCON	FY 00 Plant Replacement Value if accomplished with MILCON	34. PRM PRV	Acronym not available
35. MISSION AREA	FIM Mission Area designator	36. Weighted Age	Adjusted Age depending on major restoration or modernization
37. PML CODE	Preventative Maintenance Level Code	38. AGE	Facility Age since construction or recapitalization
39. FAC UM	Facility unit of measure	40. FAC AREA	Facility Area
41. RPM PRV NEW	Acronym not available	42. MAJCOM Credit RPM	MAJCOM that funds Real Property Maintenance
43. Percent Usage	Percent that the facility is used by the primary category code use	44. Unit Cost	Unit cost per unit of measure
45. GROUP CODE	Group Code	46. TYPE INSLN REAL PRPTY	Type of Installation Real Property
47. DIST TWN CITY	Distance to the Nearest Town or City	48. INST OWN	Owning Installation Code
49. INST OWN NAME	Owning Installation Name	50. MAJ OWN	Owning MAJCOM

After reviewing the data, it was noticed that there were several duplicate facility entries at most installations. These duplicate entries were for the same facility, but identified different uses within those facilities (i.e. supply warehouse with supply administration). When trying to combine the PRV dataset with the FIM dataset as will be discussed in a later section, the duplicate facility entries in the PRV dataset were causing multiple project requirements in the combined dataset because of the different category codes. When Access combines the datasets, it searches out all the facility requirements in the FIM datasets first, then, it proceeds to the PRV dataset to look for possible matches. When Access finds a possible match, it returns the a line item requirement in the combined dataset, however, when it encounters a second facility entry in the PRV dataset, Access interprets that as a completely different match and returns another line item requirement in the combined dataset. These combined line item requirements are for the same facility requirement from FIM, but different facility entries in the PRV dataset. For example, a single facility requirement, such as the renovation of a restroom, would show up two or more times in the combined dataset with the same FIM project number and title, but different category codes from the PRV dataset. That is a result of two or more facility uses in the facility where the restroom is located. This duplication would cause significant problems (doubling those requirements that were affected) during the analysis and had to be addressed. For the purposes of this research, the primary category code for each facility was selected so that there was only one entry for each facility at each installation in the AF. In the PRV dataset, the facility entries are in numerical order, and when there are multiple entries (multiple uses), the primary category code is the first in the sequence. Therefore, using the Access query techniques, the first (primary) category code entry was isolated and returned, eliminating the duplicate entries. A separate real property dataset (PRV) was therefore created.

Revising the PRV dataset was the optimal solution; it was the logical simplification and may be improved in the future if the reporting capability in ACES is adjusted to isolate the primary category code when producing the PRV dataset. By isolating the primary category code facility entries, this reduced the total facility database in the PRV dataset from 229,679 to 208,503 total facilities in the AF. There is a concern that one of the variables of particular interest would not be correct, the real property facility area amount (mostly square footage of a facility). Each category code entry represents a portion of the overall facility with the exact square footage that the use occupies; however, selecting the primary category code entry captured the total area in a facility.

The dataset had some variables that were not all numeric, but contained alphanumeric characters as well. Most of those variables that logically could provide some causal relationship to the focus response variable were adjusted to numeric characters by an "if – then" function in Access. Table 3 indicates each of the predictor variables that were adjusted, what the values were originally, and what they were adjusted to for the analysis. Table 3 indicates only two of the thirteen variables that required adjustment, the full listing is included in Appendix B. Each of the main variables indicated in Table 3, Real Property Inventory Control Variable and Real Property Investment Code, are divided up into several subcategories indicated under the Variable Descriptions. Table 3 indicates six subcategories for Real Property Inventory Control Variable and sixteen for Real Property Investment Code. The Real Property Inventory Control Variable subcategories further delineate the types of inventory that a particular facility falls under, whether the facility is "Single Purpose" (only one function in the facility), or "Multi-Purpose Summary" (several functions or users using the same facility). Some of the subcategory values under the Real Property Category Code were already numeric characters, however, the non-numeric characters were adjusted in sequence with the numeric characters.

Table 3. Adjustments to the PRV Variables

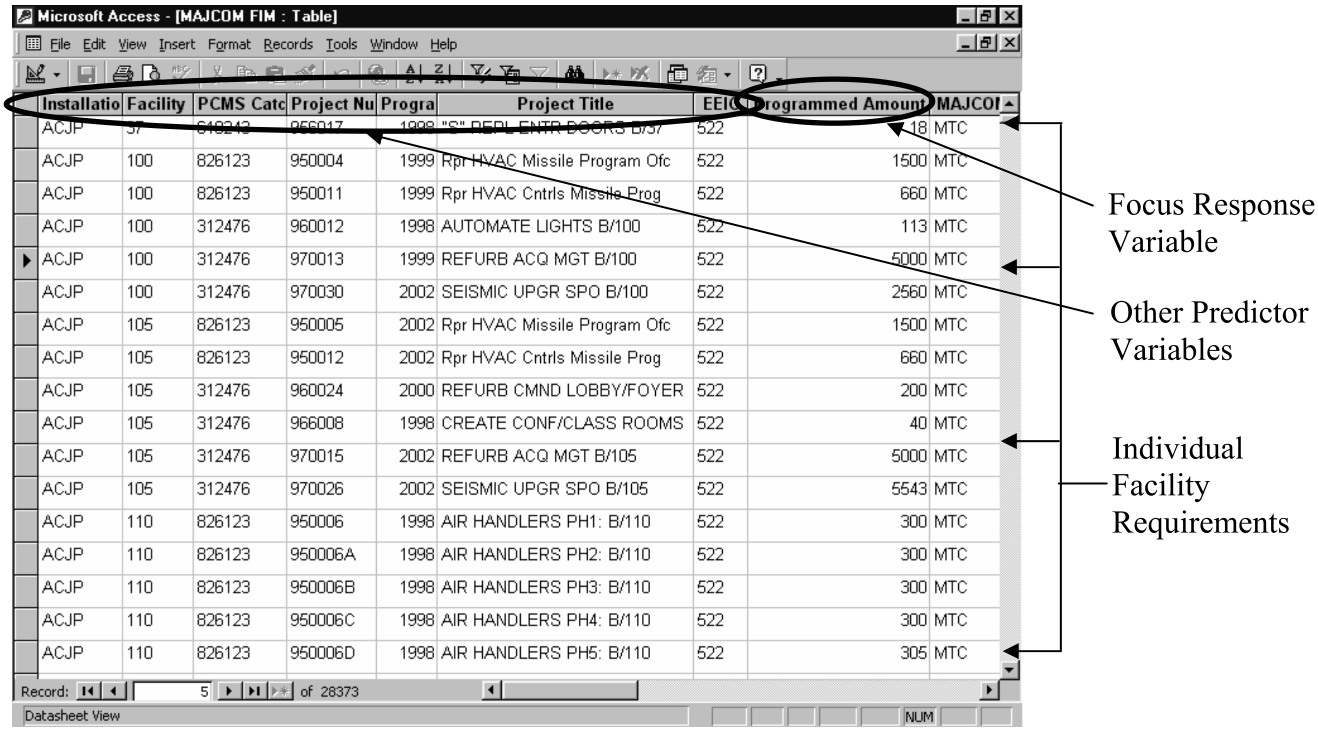
Variable Description	Original Variable Value	Adjusted Value
1. Real Property Inventory Control Variable		
Single Purpose	A	1
Multi-Purpose Summary	B	2
Land	C	3
Multi-Purpose Breakdown	D	4
Other	E	5
Utilities	X	6
2. Real Property Investment Code		
AF Owned, Other than Donated	1	1
AF Owned, Donated	2	2
AF in Lease, Includes GSA Leases	3	3
Permit from Other Agencies	4	4
Permit from other US Military Agencies	5	5
License, Easement, Temporary Land Orders	6	6
AF Owned on Leased Land	7	7
US Constructed on Foreign Land Relocatible	H	8
US Funded Construction on Foreign Land	J	9
Foreign Owned Facility (AF use at no cost by foreign agreement)	K	10
Foreign Owned Land	L	11
NATO Common Infrastructure Funded Facilities	M	12
NATO Common Infrastructure Funded Facilities US Prefinanced	N	13
US Funded Fixed Construction on Foreign Land Committed to NAT	P	14
Foreign Owned Facilities, NATO Committed (AF use at no cost)	Q	15
Joint NATO and AF use (Cost Sharing)	R	16

Once all the non-numeric variables had been adjusted, the next step was to filter the FIM datasets using the same techniques in an effort to make them manageable and understandable.

4.4.2 FIM I (FY 1997) Dataset

This section details the steps taken to manage the data in the FIM I dataset and prepare the data to be combined with the PRV dataset for final analysis. The FIM I dataset is a snapshot of all facility requirements for FY 1997 for all of the AF. The FIM I dataset was extracted from the IWIMS database, described in Chapter 2, to create the FIM report for that fiscal year and advocate for facility funding based on detailed project requirements. Every documented restoration and modernization facility requirement at every installation in the AF each year is contained in the FIM datasets. As such, the FIM I dataset provides an accurate historical reference from which to conduct the statistical regression analysis. The FIM dataset, however, does not contain the facility specific information contained in the PRV dataset and that is the reason that only the combination of the two databases will provide all the necessary variables for this analysis. The FIM I dataset is similar to the PRV dataset and includes a number of predictor variables, as indicated in Figure 12.

The predictor variables are the columns and the facility requirements are the rows in the figures spreadsheet format. The focus response variable is contained in this dataset entitled “Programmed Amount” or PA. This cost estimate variable is the focus of this research in trying to predict the total restoration costs. The other variables (columns) will be used as predictor variables during the statistical regression analysis.



Installatio	Facility	PCMS Catc	Project Nu	Progra	Project Title	EEIC	Programmed Amount	MAJCOI
ACJP	37	618243	956017	1998	"S" REPL ENTR DOORS B/37	522	18	MTC
ACJP	100	826123	950004	1999	Rpr HVAC Missile Program Ofc	522	1500	MTC
ACJP	100	826123	950011	1999	Rpr HVAC Cntrls Missile Prog	522	660	MTC
ACJP	100	312476	960012	1998	AUTOMATE LIGHTS B/100	522	113	MTC
ACJP	100	312476	970013	1999	REFURB ACQ MGT B/100	522	5000	MTC
ACJP	100	312476	970030	2002	SEISMIC UPGR SPO B/100	522	2560	MTC
ACJP	105	826123	950005	2002	Rpr HVAC Missile Program Ofc	522	1500	MTC
ACJP	105	826123	950012	2002	Rpr HVAC Cntrls Missile Prog	522	660	MTC
ACJP	105	312476	960024	2000	REFURB CMND LOBBY/FOYER	522	200	MTC
ACJP	105	312476	966008	1998	CREATE CONF/CLASS ROOMS	522	40	MTC
ACJP	105	312476	970015	2002	REFURB ACQ MGT B/105	522	5000	MTC
ACJP	105	312476	970026	2002	SEISMIC UPGR SPO B/105	522	5543	MTC
ACJP	110	826123	950006	1998	AIR HANDLERS PH1: B/110	522	300	MTC
ACJP	110	826123	950006A	1998	AIR HANDLERS PH2: B/110	522	300	MTC
ACJP	110	826123	950006B	1998	AIR HANDLERS PH3: B/110	522	300	MTC
ACJP	110	826123	950006C	1998	AIR HANDLERS PH4: B/110	522	300	MTC
ACJP	110	826123	950006D	1998	AIR HANDLERS PH5: B/110	522	305	MTC

Figure 12. Screenshot of the FIM I Database

The FIM I dataset contained 21 variables (the columns in Figure 12) listed in Table 4. Table 4 identifies all of the variables included in the FIM I dataset and how they were filtered, either eliminated or kept for analysis, as well as the reason why. There are three crucial variables in the FIM datasets, the "Installation Code", the "Facility Number" and the "Programmed Amount" or PA. The installation code and facility number are the two variables that were used to link the FIM datasets with PRV dataset and combine the data.

Table 4. Matrix of FIM I Variables and How They Were Filtered

Variable	**Kept for Analysis or Eliminated**	**Explanation**
Installation Code	Kept for Analysis	**Used to cross reference the FIM dataset with the PRV dataset.**
Facility Number	Kept for Analysis	**Used to cross reference the FIM dataset with the PRV dataset.**
PCMS Catcode	Kept for Analysis	Used as a proxy for facility use
Project Number	Kept for Analysis	Tracking number to differentiate projects from one another, they are used for tracking purposes and are not relevant for this analysis.
Programmed FY	Eliminated	Identifies which year an installation needs this requirement funded, but is not relevant to this study since the research is concerned with overall requirements.
Project Title	Kept for Analysis	Differentiates the different requirements, used for sorting the dataset and eliminating sustainment and modernization requirements.
EEIC	Kept for Analysis	Used to isolate the restoration (522) requirements from the rest of the dataset.
Programmed Amount	**Kept for Analysis**	**This is the Focus Response Variable**
MAJCOM Providing Funds	Kept for Analysis	This variable may provide insight into how different MAJCOMs provide funding to correct requirements.
Impact Rating	Kept for Analysis	Left in to sort the data and conduct a more thorough analysis.
Justification	Eliminated	This variable provides a alphametric justification of the project, the qualitative nature of the variable provides no value to a statistical regression analysis
Current Installation Location Name	Kept for Analysis	Used to cross reference the FIM dataset with the real property inventory dataset.
Host MAJCOM	Eliminated	Redundant qualitative variable, the MAJCOM Providing Funds variable will provide a relationship to funding procedures of that MAJCOM
MAJCOM Credit	Eliminated	Redundant qualitative variable, the MAJCOM Providing Funds variable will provide a relationship to funding procedures of that MAJCOM
PRV 97 RPM	Eliminated	This is the plant replacement value of the facility that houses the project. The variable is linked to the facility and not the particular restoration requirement, there is no logical

Variable	Kept for Analysis or Eliminated	Explanation
		relationship since a requirement may be very small, but the facility enormous, or it could be the opposite.
MAJCOM Mission Area	Kept for Analysis	Each installation has a different mission, depending on the MAJCOM, which varies the Mission Area of a particular category code depending on MAJCOM. The variable was left in to sort the data and conduct a more thorough analysis.
Using MAJCOM	Eliminated	Redundant qualitative variable, the Host MAJCOM variable will provide a relationship to funding procedures of that MAJCOM
MAJCOMS Matrix	Eliminated	Redundant qualitative variable, the Host MAJCOM variable will provide a relationship to funding procedures of that MAJCOM
Weapon System	Eliminated	Variable was left blank almost entirely throughout the dataset and therefore had no value for the analysis.
Link to MAJCOM RP PRV	Eliminated	This variable was a combination of Installation Code, facility number and project number and provided no relationship at all.
MAJCOM Control Groups	Eliminated	Variable was not inputted at all.

Once the predictor variables were filtered as indicated in Table 4, the remaining data was sorted by EEIC. The element of expense investment code (EEIC) is an AF coding variable that describes the classification of work. There are 7 types of EEIC's in the FIM I dataset: sustainment (521), restoration (522), minor restoration (523), modernization (529), architect-engineer design or studies (532), demolition (592), and combination restoration/modernization requirements (52X). Table 5 depicts the different EEICs, what they represent, and the subtotals for each category from the FIM I dataset along with the percentage of each EEIC from the total.

Table 5. Total Requirements by EEIC for FIM I Requirements (FY 1997)

EEIC	Description	# of Rqrmnts	Total ($000)	Percentage
521	Sustainment	274	$36,311	0.47%
522	Restoration	19,784	$6,341,114	82.67%
523	Minor Improvement	15	$903	0.01%
529	Modernization	7,162	$1,086,210	14.16%
52X	Mix of Restoration and Modernization	20	$18,955	0.25%
532	A-E Design or Study	124	$25,792	0.34%
592	Demolition	993	$161,002	2.10%
ALL		**28,372**	**$7,670,287**	**100.00%**

The FIM dataset was filtered in order to isolate the restoration requirements from the other types. This research is focused on determining a predictive model to estimate facility restoration requirements, so isolating those requirements in the historical dataset is critical to the model's validity. The circled subsection of the FIM I dataset indicates the total restoration (522) requirements which accounted for over 80 percent of the total existing facility requirements. The initial number of total AF FIM I project requirements was 28,222, valued at $7,670,287,000, indicated in Table 5. After the restoration requirements were isolated, the total number of requirements dropped to 19,784, valued at $6,341,114,000, eliminating over $1 billion in requirements.

The EEIC 52X requirements are combination projects that have restoration and modernization components. The 52X requirements that were eliminated make up only 0.25% of the total requirements and although they contain restoration requirements, differentiating the restoration amount from the modernization amount was not possible given the format and information provided, therefore those requirements were eliminated.

This filtered dataset with only restoration requirements had numerous requirements that were not tied to a particular facility. Several bases had indicated standard repair contracts, "repair base roads, repair base roofs, repair HVAC systems base-wide," without tying the requirement to specific facilities. These requirements are used as standard contracts by the AF and do not necessarily represent specific facility requirements that can be analyzed independently. Therefore, those facility restoration requirements that did not contain a facility number or contained the number "0" were eliminated. Also, without a facility number to reference, the predictor variables from the PRV dataset could not be matched and the analysis would not be accurate. The total number of requirements after filtering out the non-facility number requirements was 17,538, valued at $5,488,700,000, eliminating almost $800 million in requirements. Unfortunately, by eliminating those projects that did not contain a facility number, many of the infrastructure projects like those for roads, landscaping, sewer, electrical, etc., were eliminated. Assigning facility numbers to these infrastructure systems in the future will correct this shortcoming and the model will be improved.

Also, several bases combine multiple facility requirements together, inputting "Multi" in the facility number field. Due to the reasons provided above, analysis could not be accomplished on those requirements and they were eliminated. This could be rectified by eliminating the capability to assign multiple facilities against a single project. This solution would increase the management requirements for installation programmers; however, since it is only .25 percent, this may not be worth the manpower required. Attempts to determine the facility numbers proved too costly in terms of man-hours of research. The total amount eliminated through the elimination of non-facility numbered projects is significant (over $800 million in requirements) and will need to be corrected in the future and the analysis re-accomplished to increase the accuracy of the model. Recommendations on improving the quality of the variables are included in Chapter 5.

This initial analysis identified that the FIM I dataset contained multiple entries for facility restoration requirements for the same facility. Larger facility or infrastructure systems at AF installations can have multiple restoration project requirements that restore different segments of a facility or different geographic areas of an infrastructure system. FIM I was filtered so that the final dataset only counted each facility once per installation and summed the programmed amounts for each facility independently. These multiple requirements will adversely affect the analysis of the data by convoluting the value of certain predictor variables, like the real property area amount and plant replacement value. If there are multiple requirements in a single facility, each of those predictor variables will be counted multiple times, rather than a single time. After this last filter, the total number of line items was reduced to 10,537, valued at $5,488,700,000, which matches the total amount prior to being filtered. The FIM I dataset was now ready to be combined with the PRV dataset for final statistical regression analysis.

4.4.3 FIM II (FY 1998), FIM III (FY 1999), FIM IV (FY 2000), and FIM V (FY 2001) Datasets

All of the FIM datasets included similar variables and were filtered in much the same way as the FIM I dataset. This section outlines the similarities and difference in filtering the data of FIM II through FIM V. Table 6 is included that provides a concise synopsis of all the filtered FIM data.

The FIM II dataset was the most challenging dataset to filter because it lacked the EEIC variable, which is used to isolate the restoration requirements from the rest of the requirements. Due to the lack of the variable EEIC, the only logical manner in which to isolate the restoration requirements was to eliminate the requirements systematically by the project description. First, the dataset was sorted by the "Project Title" variable (column). In this configuration, those projects (rows) that contained words that indicated sustainment or modernization requirements like sustain, maintain, construct, install, upgrade, alter, expand, extend, modify, modernize, provide, A-E design, A-E study, and demo were eliminated. These terms are associated with project requirements that are not classified as restoration. Additional project requirements were eliminated if they were titled with Add/Alter, indicating that they were 52X requirements. These requirements are practically impossible to separate and are not a significant amount of the total requirements. Those requirements that did not have a facility number associated with the requirements were eliminated. At this point, the FIM II dataset was filtered to sum the programmed amounts by individual facilities at each installation, exactly like what was done for the FIM I dataset. The number of line items was reduced to 9,978. Table 6 provides a synopsis of the total number of requirements and total value as each FIM dataset was filtered down to the level at which they could be combined with the PRV dataset.

Note that in the row "Total Number of Initial Rqrmts", the total requirements in the FIM dataset drop dramatically between FIM II and FIM III. This drop in total requirements was due to the migration of data from the old IWIMS system to the new ACES-PM information management system. The data was significantly scrubbed and only those requirements that were valid and current were transferred. The overall value of the requirements continues to be comparable to the other datasets even though the number of requirements appear to be much less. Each FIM year, the total value of facility restoration and modernization requirements went down. Some of this was due to facility requirements being funded and accomplished, but the rest was a continuing effort to clean up the ACES database and ensure that only valid, current facility requirements are in the system.

Table 6. FIM I through FIM V Matrix - Sum Total of Filtered Data

Filtering Step	FIM I	FIM II	FIM III	FIM IV	FIM V
Total Number of Initial Rqrmnts	28,372	26,084	18,586	20,629	19,220
Total Cost of Initial Rqrmnts ($000)	$7,670,287	$7,424,403	$7,310,252	$6,875,193	$6,127,539
Number of Only Restoration Rqrmnts	19,577	19,394	11,374	12,951	12,403
Cost of Only Restoration Rqrmnts ($000)	$6,341,114	$6,336,639	$6,094,598	$5,443,755	$4,932,748
Number of Restoration Rqrmnts W/Facility Nbrs	17,538	16,545	9,974	11,505	12,216
Cost of Restoration Rqrmnts W/Facility Nbrs ($000)	$5,488,700	$5,428,349	$5,004,008	$4,909,532	$4,833,180
Number of Line Item Rqrmnts to Combine W/PRV	10,537	9,978	5,075	7,596	7,818
Cost of Line Item Rqrmnts to Combine W/PRV ($000)	$5,488,700	$5,428,349	$5,004,008	$4,909,532	$4,833,180
Percent of Restoration Requirements Lost During Filtering	86.6%	85.6%	82.1%	90.2%	98%

Note that in the row "Number of Line Item Rqrmts to combine W/PRV", the number of facility restoration requirements that filtered through to the final datasets jumped dramatically between FIM III and FIM IV. Once the entire facility requirement database was transferred to ACES, FIM III was the last year to require facility numbers to be inputted in a five-digit zip-code format. Regardless of the actual facility number, installations were required to input five digits into the variable field, so building 115 would be inputted as 00115. This mismatch resulted in a low transfer rate when the FIM datasets were combined with the PRV datasets (FIM I - FIM III), but the transfer percentage rate greatly increased when the policy shifted before FIM IV. The policy shift allowed the facility numbers to inputted as necessary, with no requirement for five full digits. The final cost of line item requirements in Table 6 does not vary significantly from FIM I to FIM V; there is less than a 12 percent difference, and the steady decline in overall amount would indicate that the requirements are being funded at a rate faster than new requirements emerge.

The FIM II dataset had an additional challenge that was encountered only when an attempt was made to combine the dataset with the PRV dataset. The FIM II data did not contain the “Installation Code”, which is a four digit alphanumeric code that is different for every installation in the AF. The variable, along with the facility number, was used to combine all the FIM datasets with the PRV datasets. The “Installation Name” was used as a substitute to combine the datasets, but was a time consuming exercise. The Installation Name in the FIM II dataset was truncated to only 17 characters in length. When combining datasets or tables, Microsoft Access looks for identical matches, which proved to be a problem since the PRV dataset allowed installation names up to 40 characters in length. Access allows variable properties to be manipulated, so the PRV dataset’s variable, “INST NAME 40”, was truncated to 17 characters to match the FIM II dataset.

There was another minor adjustment that needed to be made with the PRV dataset. The Royal Air Force (RAF) installations in the United Kingdom all began with

"RAF", such as RAF Alconbury. The FIM II dataset did not contain that designation and using a function in Access, those prefixes were eliminated when they occurred. The resulting dataset of almost 10,000 line items was now ready to be combined with the PRV dataset and transferred into JMP 5 for analysis.

The FIM III contained significantly less data variables when first supplied for this research, and was missing a critical variable, the facility number, making it impossible to combine with the PRV dataset. Without this variable, the FIM III dataset could not be analyzed except for the total amount of requirements. However, after consultation with the office that provided the FIM dataset, HQ USAF/ILE, the raw data was provided and included the key facility number variable, so an analysis could be accomplished. The new FIM III dataset contained the facility number variable and the filtering was accomplished just like the FIM I dataset. The FIM III dataset only contained restoration (522) and modernization (529) requirements, unlike the FIM I and II datasets (four to seven EEICs), so filtering was somewhat easier. The results of each filtering step are indicated in Table 6.

The FIM IV and FIM V dataset contained all the necessary variables and were filtered in much the same way as the FIM I and FIM III dataset. The FIM IV dataset contained numerous sorting variables used by programmers to sort the data and those variables were not necessary. The FIM IV dataset only contained restoration (79.2 percent of the total) and modernization (20.8 percent of the total) requirements, just like FIM III. This made isolating the restoration (522) requirements very simple using Access. The FIM V dataset, however, once again had the combination restoration/modernization (52X) requirements included with the restoration and modernization requirements. The combination requirements represented only 2.4 percent ($148,530,484) of the total requirement ($6,127,538,971), with restoration (522) making up 80.5 percent ($4,932,747,681) and modernization taking up the remaining 17.1 percent ($1,046,260,806). As indicated in the FIM I and FIM II sections, the 52X requirements are almost impossible to separate and the 2.4 percent does not represent a significant amount to warrant the tremendous effort it would take to separate the values. The filtered totals for FIM IV and FIM V are indicated in Table 6 above. Now, all five datasets were ready to be combined with the PRV dataset for final statistical regression analysis.

4.4.4 Combining the PRV (FY 2000) Dataset and the FIM Datasets

This section identifies the steps taken to combine the two datasets into a single dataset for analysis. Each database, alone, did not provide enough information to conduct the analysis, only by combining the two datasets was an accurate and meaningful analysis possible. Combining the databases was done in steps. First, the steps will be introduced and then discussed in depth in subsequent paragraphs. The end result was five combined datasets that were in the same format that could then be transferred for statistical analysis.

Combining the two datasets is a simple function in Microsoft Access and the first step is linking one or more variables. By linking variables, all of the requirements in the FIM datasets were transferred with the corresponding facility specific information from the PRV dataset into a combined dataset. However, due to lack of precise matches, there were requirements lost during this filtering. Once the datasets were combined, the final datasets were once again filtered to eliminate requirements that did not have inputs for all the variables. If a requirement lacked an input for a pertinent variable, it could not be used in the analysis. Finally, the combined dataset was set up in an independent table in Access and made ready to be transferred into the JMP 5 statistical software.

The first step in combining the two was linking the installation code and the facility numbers of the PRV dataset and the FIM datasets. By creating this link all of the facility specific variables contained in the PRV dataset could be combined with the corresponding facility requirements contained in the FIM databases and allow for a complete analysis of all pertinent variables. Once that was accomplished, a report was generated that indicated that not all the filtered FIM requirements transferred. This occurred because the facility numbers in the FIM datasets do not always correspond with those in the PRV dataset. Most of the mismatches could have occurred because initial guidance for extracting FIM I data included that the facility numbers be 5 full digits like a zipcode, even if it was a low facility number (i.e., facility number 210 would be changed to 00210 in the FIM I dataset). Some bases inadvertently inputted an alpha character with the facility number in the FIM dataset to possibly divide a large building up into more manageable sections for administrative purposes. Additionally, the research was limited to only one PRV dataset, which was a snapshot in time taken in FY 2000. This one PRV dataset was combined with five years of FIM requirements. There is a potential that the facility numbers could have changed, the facilities could be new, or the facilities could have been demolished.

Only those requirement records that exactly matched both datasets were transferred into the new combined set. Initially, prior to combining multiple same facility requirements, the total number of restoration requirements in FIM I was 17,538, valued at $5,488,700,000 (see Table 6). This dataset was combined with the PRV first and returned 12,478 total FIM requirements, valued at $4,125,765,000; over 5,000 requirements were eliminated, valued at over $700 million. This low transfer rate can be attributable to the reasons above as well as the fact that this is the oldest set of data and originated from an information management system (IWIMS) that is archaic and in the process of being replaced. This is a significant amount of requirements, but it was too difficult to manually combine the two datasets and transferring the information using Microsoft Access was the least labor intensive. The other FIM datasets were much more consistent and more of the records in the two different datasets were combined successfully.

There were also 38 project requirements in the FIM I dataset that did not have values in all the predictor variables, these requirements were mostly landscaping projects and therefore did not have any facility specific information inputted, like age, construction type code, etc., but did have facility numbers. These requirements were eliminated since they would have diluted the overall value of the inputted variables. These 38 projects were valued at $12,717,000. Some installations will designate parks and other landscaped areas with a facility number to track expenditures (grounds maintenance costs), but because they are not normal facilities, the other variables are not inputted.

The combined FIM I/PRV dataset was transferred from Microsoft Access to the JMP 5 statistical analysis software. This is a simple procedure accomplished by opening the JMP software and then opening the Access datafile as a new JMP file. All of the variables (columns) and facility requirements (rows) transferred seamlessly. Figure 13 is a screenshot of the database once it had been transferred to JMP. The columns represent the different variables that were used during the analysis and the rows are the facility line item requirements.

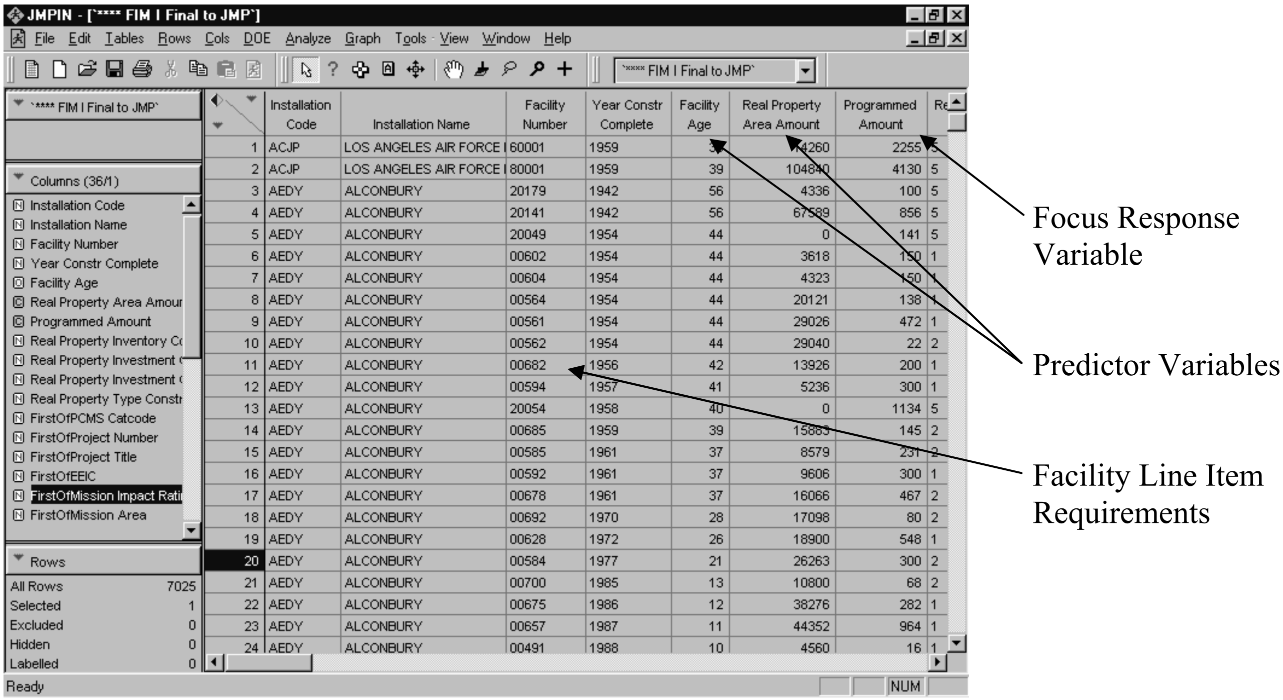


Figure 13. Screenshot of the FIM I Dataset in JMP

An initial analysis on the data was run to determine if the dataset that was transferred was complete and that the results were significant. This preliminary analysis proved to be very insignificant, returning an R-square value of only 0.05, which is significantly less that what was expected. R-square value is explained later as well as what values are significant. The variables that proved to be most significant in the preliminary analysis were the plant replacement value, mission impact rating, owning MAJCOM, age of the facility, real property type construction code, and the mission area. With an R-square value so low, it indicated that there could be a problem with the data.

The logical reason that the preliminary analysis results using the FIM I/PRV dataset were so insignificant was that there were several project requirements in large facilities, but the facility specific data was inputted each time for each facility requirement, discussed in the previous section. It was determined that the total restoration requirements for each facility needed to be summed before the information was transferred. Filtering the data in Access was simple, developing a query that returned each facility at an installation only once, and it summed the programmed amounts for all projects inputted for each facility.

Also, the PRV dataset is a snapshot of facilities taken in the entire AF in the summer of FY 2000. Therefore, the age and PRV of each facility needed to be adjusted in each of the years except for FY 2000. For FIM I, the age of facilities were reduced by three years, for FIM II the reduction was two years, for FIM III the reduction was one year, for FIM IV there was no change, for FIM V there was a positive one year adjustment. The PRV was adjusted using an inflation factor developed by the OSD Comptroller and explained in the "Plant Replacement Value (PRV) Primer" prepared by AF/ILEP dated 1 Oct 01 (48:2). The adjustment factors that were multiplied to the FY 2000 PRV were: 1997 (0.973), 1998 (0.981), 1999 (0.989), 2000 (1.000), and 2001 (1.017). These adjustments ensured that the data used during the analysis was as accurate as possible. If these adjustments were not made, the significance of the age variable and PRV may be questionable depending on the final results of the analysis.

After this final adjustment and filtering, the result was a reduction in the number of line item facility requirements to 7,025 for FIM I. However, these cannot be referred to as total project requirements any longer; rather they are the number of facilities in the

AF inventory that had facility restoration requirements. The programmed amount sum did not change significantly and was now $4,106,779,000. This methodology was repeated for FIM II through FIM V datasets as indicated below.

The combination of the PRV and FIM II datasets returned 9,045 line items of facilities and their requirements. Compared to the filtered 9,978 line items from the FIM II dataset alone (from Table 6), the amount transferred was significant (91%) and indicated the installation users did a much better job of inputting project data correctly. The total for the combined dataset was valued at $4,958,740,000, and this dataset was transferred to JMP 5 for analysis. There were 35 records (mostly landscaping requirements) that did not contain a facility age and were not included in the 9,045 dataset that was transferred. This happened in FIM IV and FIM V datasets as well. Table 5 indicates the consolidated results from the combination of all five FIM datasets with the PRV datasets and the total value of requirements of each combined dataset that was transferred to JMP for analysis. The percentage indicated in the last row of Table 5 indicates the percentage of the final combined dataset compared to the initial FIM dataset; the percentage change indicates that installation programmers probably increased their accuracy over the years regarding inputting the data, but many other factors could have been involved that will not be explored here.

Now that all of the FIM datasets have been combined with the PRV dataset, there are 5 sets of data that need to be transferred to the statistical software package to run the regression analysis and begin to develop the model.

Table 7. Combination Results of FIM and PRV Datasets

Filtering Step	FIM I	FIM II	FIM III	FIM IV	FIM V
Initial Number of FIM Requirements before Combining with PRV	10,537	9,978	5,075	7,596	7,818
Initial Value of FIM Requirements ($000)	$5,488,700	$5,428,349	$5,004,008	$4,909,532	$4,833,180
Total Number of Requirements after FIM was Combined with PRV	7,025	9,045	4,817	7,285	7,483
Value of the Combined Dataset ($000)	$4,106,779	$4,958,740	$4,448,694	$4,677,078	$4,457,869
Percentage of Final Total Value Compared to Initial	74.8%	91.3%	88.9%	95.3%	92.2%

4.5 Step 4 – Build the Model

This section describes the details of the statistical regression analysis, the results of the different variations explored, and the final model that was developed. Once the data was transferred to JMP and all the variables were coded correctly for analysis, each combined dataset was run through the stepwise regression analysis separately. The JMP software allows each variable to be analyzed independently during the stepwise regression, but also will analyze the dataset and return all the significant predictor variables in order of significance. All five FIM/PRV combination datasets were analyzed and there is a table at the end of this section that summarizes the results. The results from the five dataset analyses were averaged to determine the coefficients for the final predictive model.

4.5.1 Statistical Regression Analysis

This section identifies the step-by-step procedures used in analyzing the FIM data in JMP 5. Each FIM year dataset was analyzed independently in order to compare them, and then averaged their results so that the overall model would be more accurate. In some instances some of the data in of the FIM datasets, following FIM I, contained many of the same facility restoration requirements. When facility requirements were not funded and accomplished in a given year, they were carried over to the next fiscal year, canceled, or combined with other requirements to create a different requirement.

The first step taken in the analysis was to verify that all of the data had transferred and the program had not made any adjustments. When transferring data, JMP will interpret what type of data is in each column, whether it is text (like project title) or numeric (like facility age). Some of the variables needed to be adjusted to numeric in order to run the analysis; sometimes even data composed of numbers is interpreted by JMP to be characters. A step-wise regression analysis was conducted on each combined dataset. During a stepwise regression analysis, all of the variables are inputted into the comparison, the software program runs through the regression analysis, and returns each predictor variable in order of greatest causal relationship to least.

The combined FIM I/PRV dataset was analyzed first. The stepwise regression resulted in an R-square of .1398, or 14 percent. The R-square value is the "multiple coefficient of determination" and explains what proportion of the variance of the focus response variable is accounted for by all the predictor variables combined (28:182). In simple terms, the closer the R-square value is to 100 percent, the more accurate the prediction because more of the variance is explained. For example, if someone is trying to estimate whether to place a bet and the R-square value is 0.90, then the probability of the outcome occurring as predicted is very good, since 90 percent of the variance has been explained.

When developing predictive models, explaining the variance is very important, but the value of the R-square returned depends on the system being evaluated and the desires of the decision maker that is using the model. A judgment must be made on the basis of the consequences of the various outcomes of the decision using this applied setting (31:30). For the purposes of this research, acquiring a R-square value between 0.30 to 0.50 would provide some value to the overall process of estimating restoration requirements and would have been deemed significant due to the substantial variance in the way that installations handle facilities and infrastructure differently. Subsequently, a R-square value of 0.14 is not significant and using the results of this analysis to make predictions will not be very accurate. However, some value is added by understanding the order in which the variables were selected during the stepwise regression. Figure 14 depicts the JMP 5 results for the FIM I data. The figure identifies all of the variables independently, and each of the statistical results.

In Figure 14, the total R-square value is indicated directly under the Current Estimate block. The Step History indicates the order in which the regression analysis selected the predictor variables, in precedence order of most causal relationship to least. The R-Square value for the first variable, Real Property Area Amount is 0.0834, and the next variable contributed the next greatest causal relationship was the FY 2000 Plant Replacement Value (PRV), which increased the R-square value to 0.1100. As each predictor is brought into the analysis, they act in concert in reducing the error in explaining the response variable. The estimate coefficient value is used as the coefficient to each of the predictor variables in the final predictive model. Notice that the stepwise regression analysis did not utilize all of the variables. Those variables that were not selected, real property type construction code, state/country code, and installation type of real property, did not provide any causal relationship in predicting the response variable in the case of the FIM I dataset.

Stepwise Fit

Response: Programmed Amount

Stepwise Regression Control

Prob to Enter 0.250

Prob to Leave 0.100

Direction Forward

3 rows not used due to missing values.

Current Estimates

SSE	DFE	MSE	RSquare	RSquare Adj	Cp	AIC
1.3613e10	7039	1934009.4	0.1398	0.1383	13.034782	102106.9

Lock	Entered	Parameter	Estimate	nDF	SS	"F Ratio"	"Prob>F"
☑	☑	Intercept	1014.1329	1	0	0.000	1.0000
☐	☑	Age	7.27720581	1	1.0674e8	55.192	0.0000
☐	☑	Real Property Area Amount	0.00194767	1	3.2668e8	168.914	0.0000
☐	☑	Real Property Inventory Control Variable	61.2329917	1	59058592	30.537	0.0000
☐	☑	Real Property Investment Code	-29.755354	1	37304058	19.288	0.0000
☐	☐	Real Property Type Construction Code	0	1	1558370	0.806	0.3694
☐	☑	Category Code Abbreviated	17.3844884	1	10921161	5.647	0.0175
☐	☑	Mission Impact Rating	200.62018	1	78215665	40.442	0.0000
☐	☑	Mission Area	-104.19235	1	36313907	18.776	0.0000
☐	☑	MAJCOM with Real Property Jurisdiction	30.838597	1	28392987	14.681	0.0001
☐	☑	MAJCOM that Provides Funds	-27.193276	1	12210249	6.313	0.0120
☐	☑	FY2000 PRV	0.00002208	1	3.3818e8	174.859	0.0000
☐	☑	Owning MAJCOM	-22.895894	1	3979139	2.057	0.1515
☐	☐	State/Country Code	0	1	2204237	1.140	0.2857
☐	☑	Group Code	24.9644652	1	8220022	4.250	0.0393
☐	☐	Installation Type of Real Property	0	1	99806.55	0.052	0.8203
☐	☑	Installation Functional Type Code	-13.775984	1	17432985	9.014	0.0027

Step History

Step	Parameter	Action	"Sig Prob"	Seq SS	RSquare	Cp	p
1	Real Property Area Amount	Entered	0.0000	1.3194e9	0.0834	451.15	2
2	FY2000 PRV	Entered	0.0000	4.2173e8	0.1100	235.12	3
3	Real Property Inventory Control Variable	Entered	0.0000	1.336e+8	0.1185	168.05	4
4	Age	Entered	0.0000	1.1443e8	0.1257	110.89	5
5	Mission Impact Rating	Entered	0.0000	77198697	0.1306	72.979	6
6	Owning MAJCOM	Entered	0.0000	42376488	0.1332	53.07	7
7	Real Property Investment Code	Entered	0.0004	24128040	0.1348	42.597	8
8	Mission Area	Entered	0.0006	23167612	0.1362	32.619	9
9	MAJCOM with Real Property Jurisdiction	Entered	0.0050	15254093	0.1372	26.733	10
10	Installation Functional Type Code	Entered	0.0045	15657162	0.1382	20.638	11
11	Category Code Abbreviated	Entered	0.0218	10191056	0.1388	17.37	12
12	MAJCOM that Provides Funds	Entered	0.0433	7901876	0.1393	15.284	13
13	Group Code	Entered	0.0393	8220022	0.1398	13.035	14

Total R-Square Value

Estimate Coefficient to be used in predictive model (Beta coefficient)

All of the Predictor Variables considered

Step History indicates the order in which the Variables were selected

Cumulative R-Square for each Variable

Figure 14. FIM I Stepwise Statistical Regression Analysis

Research indicated that certain variables should have a causal relationship with the response variable and those variables were area, original cost, age, construction type, use, and climate. Most of these variables were returned by the stepwise analysis (FIM I/PRV dataset) as having some significance, except for construction type and climate (represented by State/Country Code). For this dataset, these two variables did not contribute enough significance to be returned; they did not add another 0.0001 to the cumulative R-Square value. It is possible that the other variables diluted the importance of these variables during the stepwise procedures. The more variables that are considered, the less each variable can contribute to the overall significance.

The AF specific field variables may or may not provide much significance to the predictive model. The use of those fields is not applicable to other applications of this model outside the AF. However, the other services and even industry may have similar categorical fields that delineate geographically separated units or division much like the AF specific variables, but for the purposes of this research, the variables would be removed from consideration. The MAJCOM fields were eliminated because they only differentiate from how a MAJCOM handles their funds are not necessarily universally applicable. Other organizations may not break up their physical plant in the same way that the AF does, which is a combination of mission (i.e. ACC, AMC, AETC, etc.) and geographical (PACAF, USAFE) divisions. If a MAJCOM properly sustains their facility inventory, then fewer restoration requirements would be included in the dataset and with a smaller number input, there would be a stronger relationship. It was determined that in order to make this research and model more applicable to all interested parties, including other military services and civilian corporations, those variables specifically related to the

AF were removed from the analysis from this point on. This could possibly be an area for future research in that these variables may provide some significance. Industry often has different divisions or plants that are similar to the separate MAJCOMs, so this type of further analysis may prove important.

Figure 15 reflects the same stepwise regression analysis using predictor variables that are real property specific and not based on AF specific items. The R-Square value is approximately 13 percent, no improvement, and includes the Real Property Area Amount (facility area), FY2000 PRV (variation on original cost), Real Property Inventory Control Variable (generic type of facility), Age, Real Property Investment Code (generic type of funding that constructed or owns the facility), and the Category Code Abbreviated (use).

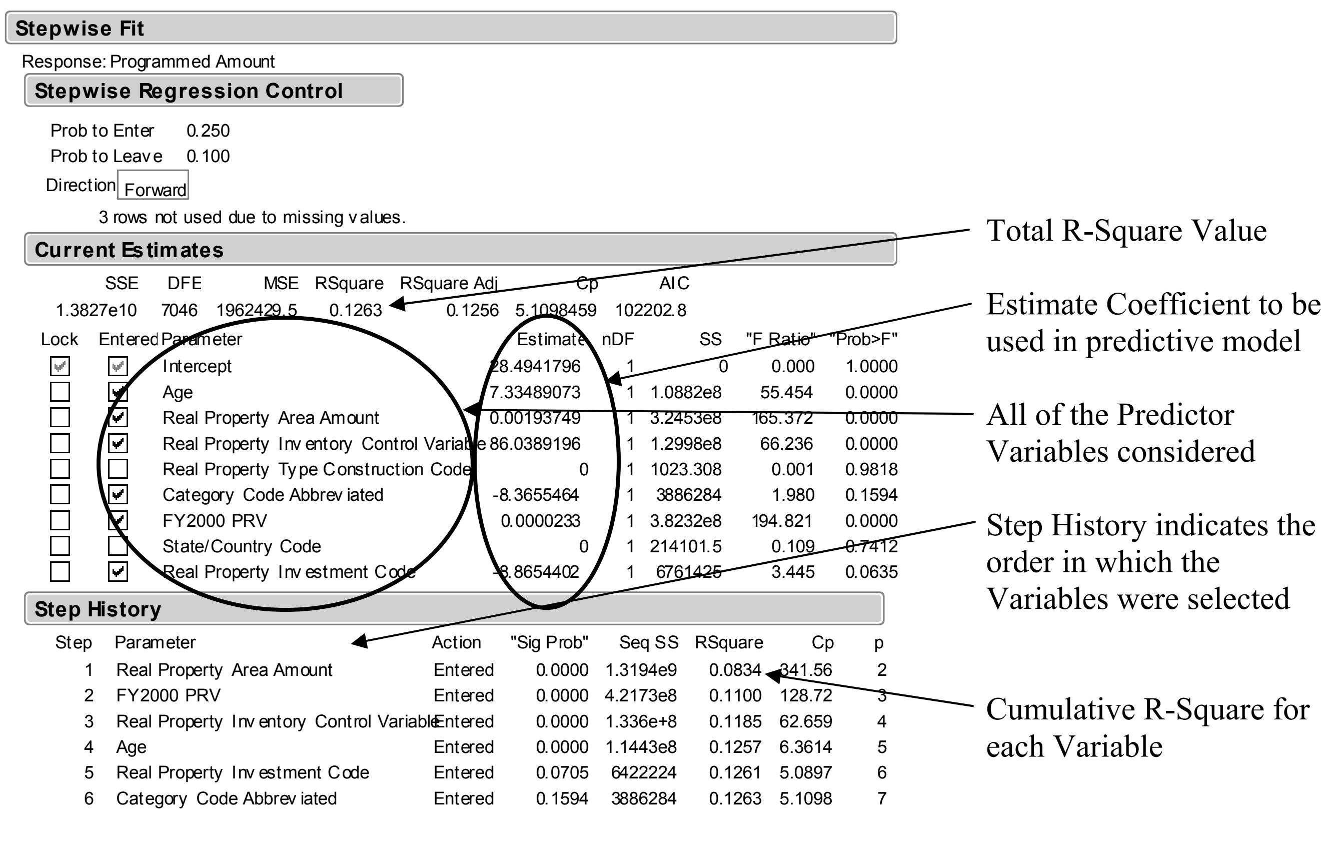


Figure 15. Revised FIM I Stepwise Statistical Regression Analysis

The ( ) indicate the more generic industry terms for the AF specific variable names. The Real Property Type Construction Code (construction type) and the State/Country Code (proxy for climate) did not provide any significant causal relationship in this dataset, otherwise they would have been selected by the stepwise analysis.

For the Real Property Type Construction Code, this may be due to the generic facility types that are standard inputs to the ACES-RP module such as: relocatable structure, hardened facility, chemical and biological facility, permanent facility, temporary facility, etc. Over 90% of all the line items were considered permanent facilities, which dilutes this predictor variable's possible causal relationship to the focus response variable. These facility types could be adjusted to a more descriptive nature like brick facility, metal facility, wood facility, stucco facility, etc, which may improve future analysis results. The variable existed in the IWIMS information management system, but when the database was transferred to ACES, the variable ("Material" field in the Facility Information view) became a non-mandatory field and most installations do not take the time to input the variable (7:1). Also, the State/Country Code is being used as a proxy for climate, whereas many states have similar climates and should be combined. For this research, however, that adjustment was not accomplished due to the time required to manually code in the climate values. Recommend that a new variable be added to the real property inventory to track the climate an installation is located in.

Another statistical test to evaluate the causal relationship between predictor variables and a focus response variable is the least squares method. This method was done which produced a leverage plot of all the variables, Figure 16, and then each variable independently, illustrated by Figure 17 using the Real Property Area Amount predictor variable for example. Each of the data points on the graph in Figure 16 indicate a cost or programmed amount of a facility project requirements. The x-axis represents the predicted programmed amount using the complete model calculations values determined by the combination of all six of the predictor variables selected in the final FIM I/PRV dataset analysis, which are indicated under the “Step History” in Figure 15. The y-axis represent the actual programmed amounts from the FIM I historical dataset that represents each facility requirement. The two dashed lines represent the range that is

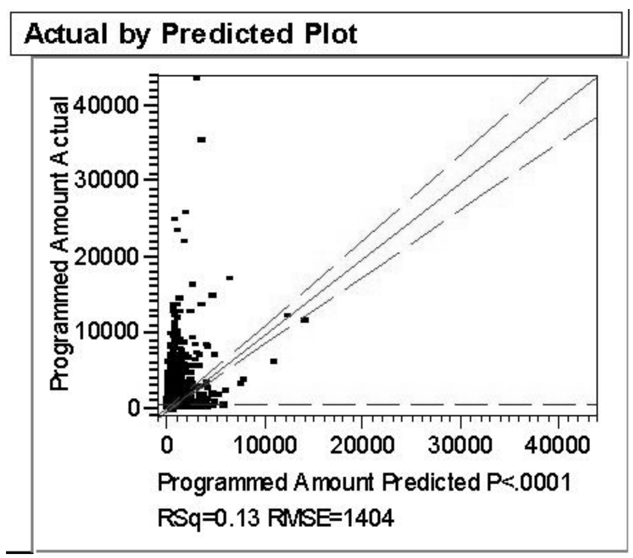


Figure 16. Leverage Plot for All Significant FIM I Predictor Variables

desired and if the data analysis had returned a high R-square value, most of the data points would have been within that range. The actual graph in Figure 16 though, is a buckshot pattern indicating hardly any causal relationship resulting in a R-square value of only 0.13. Figure 17 represents the causal relationship results between the Real Property Area Amount predictor variable and the programmed amount response variable; it is representative of the predictive plots for each independent predictor variable. The x-axis in the Figure 17 graph indicates the predicted programmed amount using only the Real

Property Area Amount predictor variable. The y-axis is the remains the actual programmed amounts. Once again, this results in a buckshot pattern, only this time the model results actually indicate the possibility of a negative predicted amount. This extrapolation often occurs when dealing with this many data points and this complicated of a relationship. Both leverage plots confirm the R-square results and indicate an insignificant causal relationship.

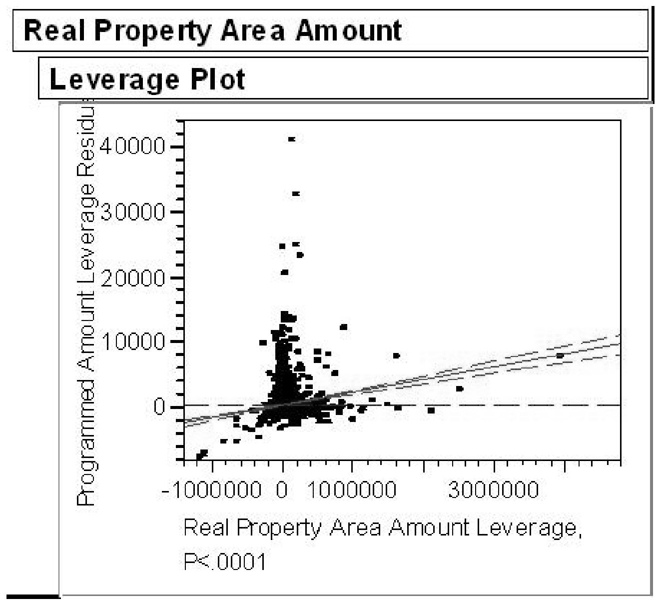


Figure 17. Leverage Plot for Only Real Property Area Amount Predictor Variable

The combined FIM II/PRV dataset was analyzed second. The results were less significant than the results of the FIM I/PRV dataset, but did confirm the importance of certain predictor variables. The stepwise regression resulted in an R-Square value of .0722, or 7 percent. This value is even less significant than the FIM I dataset, but again, the order in which the variables were selected during the stepwise regression is of importance. Each of the other combined FIM/PRV datasets were analyzed using the same techniques and Table 6 below provides a consolidated comparison of the five different datasets. The first column indicates the different datasets; the second column lists the order in which the variables were selected through stepwise regression and the subsequent cumulative R-square value.

Table 8. Comparison Chart of Stepwise Regression Results for the 5 Datasets

Dataset	Order Variables Were Selected	Cumulative R-Square Value
FIM I	1. Real Property Area Amount	0.0834
	2. Plant Replacement Value	0.1100
	3. Real Property Inventory Control Variable	0.1185
	4. Facility Age	0.1257
	5. Real Property Investment Code	0.1261
	6. PCMS Category Code	**0.1263**
FIM II	1. Plant Replacement Value	0.0529
	2. Real Property Area Amount	0.0640
	3. Real Property Type Construction Code	0.0693
	4. Facility Age	0.0705
	5. Real Property Inventory Control Variable	**0.0710**
FIM III	1. Plant Replacement Value	0.0811
	2. Real Property Area Amount	0.1002
	3. Real Property Inventory Control Variable	0.1058
	4. State/Country Code	0.1086
	5. Facility Age	0.1110
	6. PCMS Category Code	0.1119
	7. Real Property Type Construction Code	0.1125
	8. Real Property Investment Code	**0.1128**
FIM IV	1. Plant Replacement Value	0.0713
	2. Real Property Area Amount	0.0972
	3. Real Property Inventory Control Variable	0.1050
	4. Facility Age	0.1081
	5. Real Property Type Construction Code	0.1095
	6. PCMS Category Code	0.1103
	7. State/Country Code	**0.1106**
FIM V	1. Plant Replacement Value	0.0818
	2. Real Property Type Construction Code	0.1008
	3. Real Property Inventory Control Variable	0.1056
	4. Real Property Area Amount	0.1104
	5. Facility Age	**0.1131**

The order of the variables shifts slightly from dataset to dataset, but the significant predictor variables of plant replacement value and real property area amount are consistently at the top.

During the initial analysis of FIM IV data, the Installation Functional Type Code and Installation Type of Real Property variables provided some significance in the initial stepwise regression. The Installation Functional Type Code indicates the general purpose of the installation like airfield installation, depot, or industrial. The Installation Type of Real Property is a macro variable indicating if the installation is a primary, auxiliary, or leased installation. However, those variables are not specific to individual facilities, rather those are installation variables and probably only address an installation's ability to sustain the installation facility inventory. Therefore, in a continuing effort to focus only on specific facility related variables, those variables were removed and the analysis for FIM I, II, and IV was re-accomplished without those variables, the final values are represented in Table 6 above.

The results of the stepwise regression analysis did not produce the expected results. The highest R-square value, 12.6 percent, is extremely low and a predictive model based on the results of this analysis would not be very accurate at all. However, the remaining steps in this methodology were accomplished and a overall model was developed. This model though, should not be used to estimate restoration requirements, but may be used to allocate resources once funding is provided as will be explained in Chapter 5.

The five combined FIM/PRV datasets were analyzed separately and then the results were averaged out to create a moderate predictive model. Table 9 represents a synopsis of the final stepwise regression results. The first column, entitled Predictor Variables, first lists the variables and then is broken into three sub-parts. These are the order in which the variable was selected (Order), the individual R-Square value in relationship to the response variable (Ind. R-Square), and the final estimate coefficient (Final Estimate). The next five columns are the individual results from the combined FIM/PRV datasets. The final column is the averages of the five datasets for the order and final estimate values. Also, the last row indicates the Y-intercept values for each of the five datasets and also has an average. The Y-intercept (β_0) is part of the overall formula equation and will be explained in a subsequent section. The (β_x) designator for each average "Estimate" for each variable will be used in the development of the final predictive model in the next section. Each predictor variable was also assigned a (X_x) designator that will be used in the development of the final predictive model in the next section.

The table indicates the sequential order of each predictor variable in each FIM dataset. The order below is a result of the averages of the selection order between the different FIM datasets, as indicated in the last column. The first variable, plant replacement value, had an average selection order of 1.2. The overall order of the eight predictor variables is:

1. Plant Replacement Value
2. Real Property Area Amount
3. Real Property Inventory Control Variable
4. Real Property Type Construction Code
5. Facility Age
6. State/Country Code (proxy for climate)
7. PCMS Category Code (proxy for use)
8. Real Property Investment Code

Table 9. Summary of Stepwise Statistical Regression Analysis

Predictor Variables		FIM I	FIM II	FIM III	FIM IV	FIM V	Averages
Real Property Area Amount (X_2)	Order	**1**	2	2	2	4	2.2
	Ind. R-Square	0.0833	0.0320	0.0608	0.0665	0.0507	-
	Final Estimate	0.001936	0.001052	0.001485	0.001285	0.000795	.0013106 **(β_2)**
Plant Replacement Value (cost to build) (X_1)	Order	2	**1**	**1**	**1**	**1**	1.2
	Ind. R-Square	0.0828	0.0529	0.0811	0.0713	0.0818	-
	Final Estimate	0.0000233	0.0000191	0.0000173	0.0000191	0.0000160	0.0000190 **(β_1)**
Real Property Inventory Control Variable (X_3)	Order	3	5	3	3	3	3.4
	Ind. R-Square	0.022	0.0090	0.0189	0.0178	0.0286	-
	Final Estimate	86.534	27.644	69.042	57.754	65.231	61.241 **(β_3)**
Real Property Investment Code (X_8)	Order	5	-	8	-	-	6.5
	Ind. R-Square	0.0022	-	0.0054	-	-	-
	Final Estimate	-8.930	-	-11.071	-	-	-10.001 **(β_8)**
Real Property Type Construction Code (X_4)	Order	-	3	7	5	2	4.25
	Ind. R-Square	-	0.0142	0.0179	0.0210	0.0284	-
	Final Estimate	-	-48.683	-21.637	-24.370	-41.777	-34.117 **(β_4)**
PCMS Category Code (proxy for use) (X_7)	Order	6	-	6	6	-	6
	Ind. R-Square	0.0000	-	0.0006	0.0006	-	-
	Final Estimate	-8.306	-	-17.739	-13.387	-	-13.144 **(β_7)**
Facility Age (X_5)	Order	4	4	5	4	5	4.4
	Ind. R-Square	0.0155	0.0054	0.0089	0.0091	0.0107	-
	Final Estimate	7.308	3.640	4.917	4.269	3.868	4.800 **(β_5)**
State/Country Code (proxy for climate) (X_6)	Order	-	-	4	7	-	5.5
	Ind. R-Square	-	-	0.0035	0.0007	-	-
	Final Estimate	-	-	-3.7739	-1.1896	-	-2.482 **(β_6)**
Y-Intercept (β_0)		50.445	607.050	764.202	543.771	504.743	494.042 **(β_0)**

Improving the quality of these variables, by making them more descriptive regarding things like facility type and actual climate, may result in a different order of significance in future research and should be revisited if the information in the ACES database is improved. Results definitely show the importance of keeping facility inventory data accurate, up-to-date, and correct. The quality of this analysis is directly related to the quality of the data. Since the final results were so insignificant, additional evaluation with different variations in the data may provide some additional insight into the development of the model.

4.5.2 Variations in the FIM Datasets

This section explores the different variations that were attempted to provide further explanation of the response variable. The variations that were explored involve reducing the number of facility requirements in each dataset by eliminating the enhancement (mission impact MIN rating) requirements and then eliminating the degraded (mission impact DEG rating) requirements, leaving only the critical (mission impact CRI rating) requirements.   The final variation involved combining all five FIM datasets into one consolidated dataset. These variations are an attempt to increase the explanation, or increase the R-Square value of the stepwise regression. Although these variations may increase the R-Square value significantly, these variations are only for the purpose of justifying the importance of this methodology, and will not help in the final development of the predictive model. All facility requirements, whether important to the mission or not, are crucial in the development of the predictive model for the AF, and need to be included. Therefore, this variation analysis is only being done to check the validity of the methodology and will not produce more relevant significance for the predictive model.

The FIM IV dataset was chosen randomly to explore the first two variations: isolating the critical and degraded mission impact requirements, and isolating only the critical mission impact requirements. The FIM IV dataset was used because it included all the significant predictor variables and did not require significant sorting like the FIM II dataset.

The first variation involved filtering the FIM IV dataset to eliminate the enhancement (mission impact rating of MIN) facility project requirements to determine if the predictive accuracy of the model could be improved. Once the FIM IV dataset was filtered to isolate only the critical and degraded mission impact requirements with the programmed amounts summed by facility number, the total number of requirements dropped to 4,202. When this dataset was combined with the PRV dataset, the number dropped to 4,008 (captured 95%), valued at $3,024,304,000. This dataset was transferred for JMP analysis, and the resulting stepwise regression information is provided in Table 10. This variation returned a combined R-square of only 0.1215 or 12% (indicated in the Cum. R-Square row under the Facility Age variable in Table 10). This is slightly better than the final R-square of 0.1131 (see Table 8), for the combined FIM IV/PRV dataset.

The second variation involved filtering the FIM IV dataset to eliminate the degraded requirements (mission impact rating of DEG) as well as the enhancement (mission impact rating of MIN) facility project requirements to determine if the predictive accuracy of the model could be improved. Once the FIM IV dataset was filtered to isolate only the critical mission impact requirements with the programmed amounts summed by facility number, the total number of requirements dropped to 199. When this dataset was combined with the PRV dataset, the number dropped to 183 (captured 92%), valued at $233,662,000. This dataset was transferred for JMP analysis, and the resulting stepwise regression results are indicated in Table 10. Although the R-square value increased slightly to 0.2095 or 21 percent (indicated in the Cum. R-Square

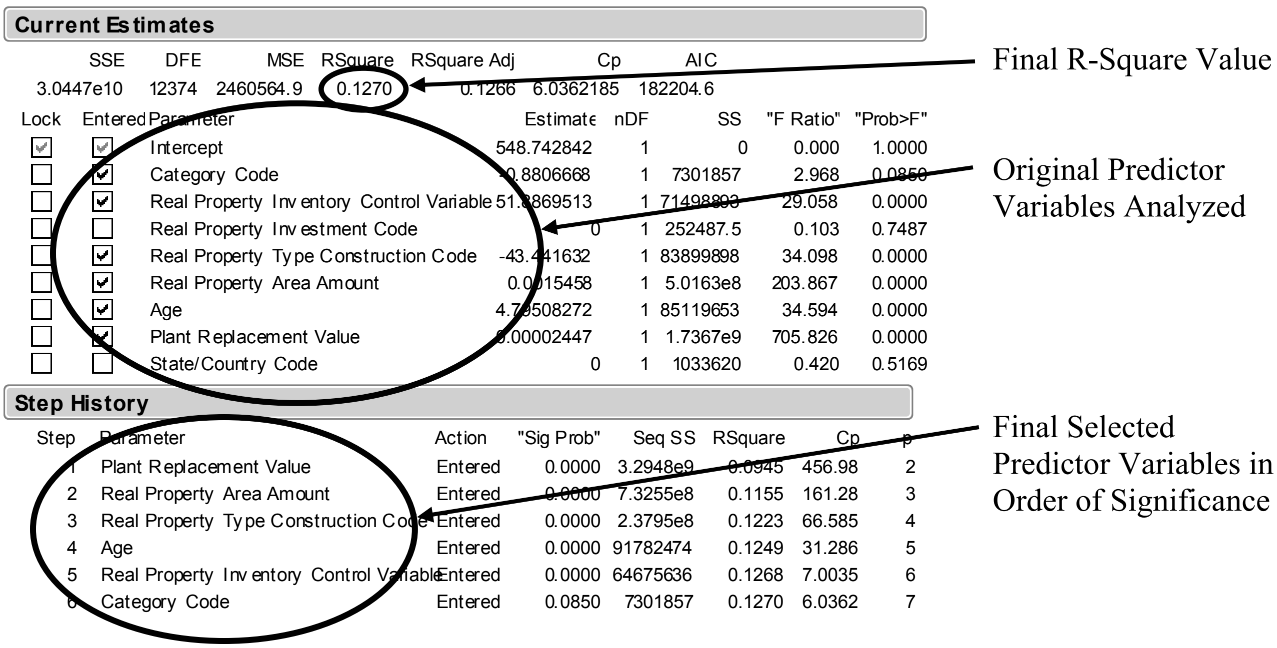
Table 10. Variations of FIM IV Dataset for Regression Analysis

Predictor Variables		**FIM IV (CRI & DEG)**	**FIM IV (CRI)**	**Averages**
Real Property Area Amount	Order	3	3	3
	Cum. R-Square	0.1129	0.2032	-
	Final Estimate	0.00084593	-0.004102	-0.001628
Plant Replacement Value (cost to build)	Order	**1**	2	1.5
	Cum. R-Square	0.0983	0.1619	-
	Final Estimate	0.00001738	0.00003799	0.0000277
Real Property Inventory Control Variable	Order	4	-	4
	Cum. R-Square	0.1166	-	-
	Final Estimate	72.875997	-	72.876
Real Property Investment Code	Order	6	4	5
	Cum. R-Square	0.1202	0.2095	-
	Final Estimate	- 16.17083	- 36.21738	- 26.1941
Real Property Type Construction Code	Order	2	**1**	1.5
	Cum. R-Square	0.1080	0.1241	-
	Final Estimate	-18.87925	- 217.6146	-118.247
PCMS Category Code (proxy for use)	Order	5	-	5
	Cum. R-Square	0.1185	-	-
	Final Estimate	-24.23965	-	-24.2397
Facility Age	Order	7	-	7
	Cum. R-Square	0.1215	-	-
	Final Estimate	3.37002	-	3.37
Y-Intercept		**590.478**	**2836.037**	**1713.26**

row under the Real Property Investment Code variable in Table 10) for this variation of the FIM IV dataset, this is still not significant and the results would not be considered an accurate regression model for predicting future values.

The final variation involved combining all five FIM/PRV datasets so that all known facility requirements were being evaluated at one time. The challenge in conducting this analysis was to ensure that when requirements carried over from one FIM year to the next, those requirements were only captured once and not multiple times. Through a set of complex Microsoft Access queries, all five of the FIM/PRV datasets were combined into one large dataset that included requirements from all five years. The first step was to combine the FIM I/PRV with the FIM II/PRV dataset. During this query, the duplicate project requirements were also tagged with a designator. Using the designator, they requirements were removed from the FIM I/PRV dataset. Now, the FIM I/PRV and FIM II/PRV datasets could be combined and the duplicate projects are only included in the FIM II/PRV dataset. The most current project requirements were kept because often the programmed amount increased from year to year as a result of inflation or scope adjustments.

The rest of the datasets were combined in the same manner until a complete dataset of all facility requirements was created. The project requirements from the FIM III dataset were unusable because of technical problems with that particular dataset, but the overall analysis of the remaining four years of facility requirements were adequate to explore the significance of this variation. The combined dataset included 23,907 facility requirements valued at $7,838,745, and included requirements from the FIM I, FIM II, FIM IV, and FIM V/PRV datasets. The next step involved combining the multiple requirements per facility into a single facility total. Once this filtering step was accomplished, the total line item requirements dropped down to 12,417. This dataset was transferred to JMP 5 for analysis and the results are indicated in Figure 18. Figure 18 is a screenshot of the stepwise regression analysis in JMP and indicates the same predictor variables as were analyzed before and it also indicates the order in which the variables were selected and the cumulative R-square value of 0.1270, or 12.7%. This variation also did not result in a significant increase over the individual dataset analysis.



Current Estimates

SSE	DFE	MSE	RSquare	RSquare Adj	Cp	AIC
3.0447e10	12374	2460564.9	0.1270	0.1266	6.0362185	182204.6

Lock	Entered	Parameter	Estimate	nDF	SS	"F Ratio"	"Prob>F"
✓	✓	Intercept	548.742842	1	0	0.000	1.0000
	✓	Category Code	-0.8806668	1	7301857	2.968	0.0850
	✓	Real Property Inventory Control Variable	51.8869513	1	71498893	29.058	0.0000
		Real Property Investment Code	0	1	252487.5	0.103	0.7487
	✓	Real Property Type Construction Code	-43.441632	1	83899898	34.098	0.0000
	✓	Real Property Area Amount	0.0015458	1	5.0163e8	203.867	0.0000
	✓	Age	4.79508272	1	85119653	34.594	0.0000
	✓	Plant Replacement Value	0.00002447	1	1.7367e9	705.826	0.0000
		State/Country Code	0	1	1033620	0.420	0.5169

Step History

Step	Parameter	Action	"Sig Prob"	Seq SS	RSquare	Cp	p
1	Plant Replacement Value	Entered	0.0000	3.2948e9	0.0945	456.98	2
2	Real Property Area Amount	Entered	0.0000	7.3255e8	0.1155	161.28	3
3	Real Property Type Construction Code	Entered	0.0000	2.3795e8	0.1223	66.585	4
4	Age	Entered	0.0000	91782474	0.1249	31.286	5
5	Real Property Inventory Control Variable	Entered	0.0000	64675636	0.1268	7.0035	6
6	Category Code	Entered	0.0850	7301857	0.1270	6.0362	7

Figure 18. Stepwise Regression Analysis of 5-year Combined Dataset

4.5.3 Development of the Final Model

This section explains the development of the formula based predictive model and establishes the optimum formula based model for this research. Due to the insignificant results from the stepwise statistical regression analysis, the model developed in this section is only representative of this research's methodology and should not be used to estimate future restoration requirements.

In developing a formula based predictive model using regression analysis, the "Estimates" from the stepwise tables for the different predictor variables are the constants that are included in the formula multiplied by their respective predictor variable. For instance, a standard regression formula would look like this:

$$\text{Estimate (E(y))} = \beta_o + \beta_1 * X_1 + \beta_2 * X_2 + \ldots + \beta_n * X_n + \varepsilon \qquad (7)$$

Where E(y) is the estimate we are trying to predict, β_o is the Y-intercept, β_1 is the "estimate" for the first predictor variable of significance, X_1 is the actual predictor variable from current data, β_2 is the "estimate" for the second predictor variable of significance, X_2 is the actual predictor variable from current data, etc., and ε is the remaining error constant that cannot be explained.

Using the averages obtained for the predictor variables in the FIM I, II, IV, and V datasets, the predictor formula model for estimating facility restoration costs for the AF would be:

$$E(y) = 494.042 + 0.0000190*X_1 + 0.0013106*X_2 + 61.241*X_3 - 34.117*X_4 + 4.800*X_5 + \varepsilon \quad (8)$$

All of these actual values were taken from Table 9, "Average" column; the 494.042 is the Y-Intercept, 0.0000190 is the (β_1) value, X_1 is Plant Replacement Value, 0.00131106 is the (β_2) value, X_2 is Real Property Area Amount, 61.241 is the (β_3) value, X_3 is Real Property Inventory Control Variable, -34.117 is the (β_4) value, X_4 is Real Property Type Construction Code, 4.800 is the (β_5) value, and X_5 is the Facility Age. Given the low significance of this model, the possible error (ε) could be substantial, possibly in the millions of dollars.

The section 4.7 will expand on a possible use for this regression model as an allocation tool once restoration funding is provided to an AF MAJCOM.

4.6 Step 5 – Validate and Test

Since the stepwise statistical regression analysis revealed that the results were insignificant, the validation and testing step of the methodology was no longer needed. Any results determined during the validation and testing step would be extremely rough, therefore this analysis was not accomplished.

4.7 Step 6 – Use to Make Predictions

The regression model should not be used to make predictions but can be used as an allocation tool to develop distribution percentages for AF installations within a MAJCOM. Once funding is allocated to a MAJCOM, this model can be used to divide the available funding up to the different installations under MAJCOM control. This section will explain how that can be done and provide an example using the Air Combat Command (ACC) MAJCOM physical plant data. ACC uses a formula based allocation method that will be compared to the regression allocation model developed during this research.

ACC is one of the largest MAJCOMs with sixteen major installations located throughout the United States. ACC's installation operations and maintenance is primarily funded by fund type code 3400, whereas the other MAJCOMs, like AFMC have other fund types to consider which complicate the ability to evenly distribute available funding. ACC uses an allocation model to distribute sustainment, restoration, & modernization by contract (SRMC) funding to these sixteen installations (1:1). If funding is made available for SRMC, ACC uses this allocation model to distribute the funds down to the installation based on four factors: facilities square footage, airfield pavements (in square yards), physical plant index (PPI), and base population. The base PPI is a rating provided to an installation based on the condition evaluation of the entire physical plant inventory by MAJCOM experts, thereby ensuring the ratings are standardized across all sixteen installations. This model uses the physical characteristics of installations to arrive at an allocation number. The number is divided by the sum of all ACC allocation numbers and multiplied by 100 to convert to a percent allocation. The percent is then multiplied with the total command funding to get the funding allocation provided to each installation. The formulas are shown below:

$$\text{Allocation Number} = [(\text{SF x } 0.35) + (\text{AF SY x } 0.15) + (\text{PPI x } 0.30) + (\text{BP x } 0.20)] \quad (9)$$

$$\text{Allocation Percent} = \frac{\text{Allocation Number}}{\Sigma \text{ of ACC's Allocation Number}} \text{ x } 100\% \quad (10)$$

$$\text{Funding Allocation} = \text{Allocation Percent x Command Funding Available} \quad (11)$$

Where SF is the facilities square footage, AF SY is the airfield pavement square yards, PPI is the physical plant index, and BP is the base population. The formula establishes a separate percentage to each of the four components as coefficients to each variable. These percentages are based on programming experience and not any statistical analysis or historical results.

The ACC allocation formula provides some measure of validity to the funds distribution, but the formula is not based on any in-depth analysis, rather it is an educated estimate as to the importance of each variable based on the experience of the personnel at ACC/CEPD. Table 11 indicates each of the sixteen ACC installations and the percentage derived from Equation 10 above. ACC uses these percentages and multiplies them by any amount of SRMC funding that is provided for distribution to the installations.

The regression model developed in this research can be used to establish percentages for each base in a MAJCOM in much the same manner as ACC does using their model. Using Equation 8 and the facility variable information from the FY2000 PRV dataset, the regression model produced the percentages indicated in Table 12 for the ACC installations. The ACC only facilities and desired predictor variables were isolated using the Access query capabilities. The resulting report was transferred to Microsoft

Table 11. Air Combat Command SRMC Allocation Percentages

Base	Base Percentage
Barkdale AFB, LA	6.87%
Beale AFB, CA	5.16%
Cannon AFB, NM	4.80%
Davis-Monthan AFB, AR	6.93%
Dyess AFB, TX	5.99%
Ellsworth AFB, SD	5.94%
Holloman AFB, NM	6.71%
Langley AFB, VA	7.67%
Minot AFB, ND	6.67%
Moody AFB, GA	5.14%
Mountain Home AFB, ID	6.81%
Nellis AFB, NV	7.89%
Offutt AFB, NE	8.13%
Seymour Johnson AFB, SC	5.37%
Shaw AFB, NC	5.14%
Whiteman AFB, MO	4.77%
TOTAL	100%

Excel in order to run the mathematical equations. Each of the ACC installations was isolated and the variables were either summed (plant replacement value and real property area amount) or were averaged (real property inventory control variable, real property type construction code, and facility age) to produce the "X" variables indicated in Equation 8. The sixteen major installations often were responsible for geographically separated sites. Those facilities and infrastructure at those sites were also included in the totals for each installation. The estimates, or β coefficients in Equation 8, are indicated at the bottom of Table 12 and were then multiplied to the predictor variables to determine the estimated restoration requirements. The restoration requirements for ACC were totaled and then that total was used to establish the percentage for each base. The first column of Table 12 represents the sixteen ACC installations; the second column indicates the total plant replacement value of all the facilities and infrastructure at each installation; the third column totals the real property area amount, the four column indicates the average rating for the real property inventory control variable, the fifth column is the average real property type construction code, the sixth column is the average facility age, the seventh column indicates the total value using Equation 8 for each installation, and the eighth column indicates the percentage for each installation from the total. The error value (ε) in Equation 8 is not considered here because that value is only used when the equation is used as a predictive model, where ε represents the possible adjustment necessary for the equation to balance once the exact figure is know. In this case, ε is not necessary because the equation is being used to determine allocation percentages that are justified based on historical data.

Table 12. Allocation Model Based on Research Regression Model

Installation Name	Plant Replacement Value	Real Property Area Amount	Real Property Inventory Control Variable	Real Property Type Construction Cole	Age	Total Restoration Requirement	Allocation Percentage
Barkdale AFB, LA	$1,689,375,770	10962556	2.44043	8.77842	32.51788	$46,965.75	6.05%
Beale AFB, CA	$1,714,050,734	9407310	1.60996	8.93818	36.91636	$45,361.08	5.85%
Cannon AFB, NM	$1,235,626,359	8397154	2.63805	8.57161	21.98039	$34,950.88	4.50%
Davis-Monthan AFB, AR	$1,416,636,511	11408350	2.55977	8.41409	27.28712	$42,362.60	5.46%
Dyess AFB, TX	$1,185,373,896	9806454	1.98108	8.64182	31.15765	$35,844.53	4.62%
Ellsworth AFB, SD	$1,782,489,002	14068602	3.07013	7.82182	26.65626	$52,848.75	6.81%
Holloman AFB, NM	$2,031,034,471	13549520	2.39219	8.36459	33.93840	$56,865.73	7.33%
Langley AFB, VA	$1,623,305,085	10336704	2.25071	8.54910	39.51685	$44,919.97	5.79%
Minot AFB, ND	$2,954,334,055	12233179	3.36241	8.79460	34.95574	$72,732.85	9.37%
Moody AFB, GA	$834,855,530	5356182	2.74643	8.23430	24.88043	$23,382.80	3.01%
Mountain Home AFB, ID	$1,548,821,625	10635829	2.35233	8.74810	32.49891	$43,862.57	5.65%
Nellis AFB, NV	$3,098,188,586	26665535	2.62296	8.24765	25.25478	$94,307.95	12.15%
Offutt AFB, NE	$2,390,048,159	13688559	1.83955	8.69830	34.57543	$63,827.04	8.23%
Seymour Johnson AFB, SC	$1,079,413,437	9140272	2.03458	8.70579	33.71998	$32,971.58	4.25%
Shaw AFB, NC	$1,062,591,054	8511790	2.18466	8.51163	32.16279	$31,836.60	4.10%
Whiteman AFB, MO	$2,064,256,602	10011096	3.14383	8.43678	29.30025	$52,880.79	6.82%
Estimate	0.0000190	0.0013106	61.24100	-34.11700	4.80000	$775,921.47	100.00%

The difference in percentages from the ACC allocation model and the regression predictive model are indicated in Table 13 below. The second column is the ACC allocation model percentages, the third column is regression model percentages and the fourth column is the difference.

Table 13. Combined Results of Each Allocation Model Percentages

Base	ACC Allocation Model (A)	Regression Prediction Model (B)	Difference (A-B)
Barkdale AFB, LA	6.87%	6.05%	0.82
Beale AFB, CA	5.16%	5.85%	-0.69
Cannon AFB, NM	4.80%	4.50%	0.30
Davis-Monthan AFB, AR	6.93%	5.46%	1.47
Dyess AFB, TX	5.99%	4.62%	1.37
Ellsworth AFB, SD	5.94%	6.81%	-0.87
Holloman AFB, NM	6.71%	7.33%	-0.62
Langley AFB, VA	7.67%	5.79%	1.88
Minot AFB, ND	6.67%	9.37%	-2.70
Moody AFB, GA	5.14%	3.02%	2.12
Mountain Home AFB, ID	6.81%	5.65%	1.16
Nellis AFB, NV	7.89%	12.15%	-4.26
Offutt AFB, NE	8.13%	8.23%	-0.10
Seymour Johnson AFB, SC	5.37%	4.25%	1.12
Shaw AFB, NC	5.14%	4.10%	1.04
Whiteman AFB, MO	4.77%	6.82%	-2.05
TOTAL	100%	100%	

There are substantial differences, indicated in Table 13, between the two allocation models. Besides PRV, the two models do not contain any other variables in common. ACC is one of the few MAJCOMs that routinely tracks and updates the physical plant index making it a usable variable. Although the regression predictive model cannot provide an accurate estimate of what the future requirements will be, it is directly derived from the historical data used by the AF, therefore the model does have some validity when used to determine percentages for allocating SRMC funding. The regression model is justified through statistical analysis of historic information whereas the ACC allocation model is a best guess model developed by knowledgeable facility programmers. The statistical regression model may have more validity when presenting decision makers with these breakout percentages.

4.8 Systematic Analysis of the AF Reporting Tools

This section presents the results of an attempt to explore potential improvements by going through the AF methodology of identifying and articulating facility requirements to decision makers using the various tools described in this research, the FSM, FIM, and IRR. The section will evaluate each reporting tool independently, identifying the positive aspects of the tools and exposing some of the areas for improvements. The analysis will include the differences and the similarities as well as possible adjustments that may further integrate the reporting tools and make them more universally understood.

The analysis focused around the facility requirements at a generic AF installation and included only those requirements for FY 2000. Moody AFB, Georgia, was randomly chosen as the generic installation because it has a typical AF operational flying mission and an average facility inventory. FY 2000 was chosen because the PRV dataset snapshot was taken in FY 2000 and the FIM IV data was available. The analysis will process through the different reporting tools and explain how to interpret the facility requirement data for a single installation. The section begins with some of the limitations of this analysis, especially the incomplete set of facility requirements that make up the IRR.

This analysis was limited to the data available for the first part of this research, which included the real property database (PRV), the FIM IV dataset, the DoD Facilities Cost Factor Handbook (17), and the FY 2001 Air Force Installations' Readiness Reporting Instructions (47). There are substantial facility requirements for FY 2000 that are not included in this analysis that would make the final results and totals derived from the reporting tools more complete. The IRR incorporates data from numerous sources that were not easily available during this research effort. The data that is missing from the IRR analysis includes facility requirements for the housing and medical facilities at the installation. The environmental requirements for the installation are kept in a separate database and are not included in the overall sustainment, restoration, and modernization totals presented here. Also missing are the large-scale MILCON requirements that were identified for FY 2000. However, the purpose of this analysis is to identify similarities and differences in the way that the different reporting tools interpret information. Therefore, there is enough data available in the FIM IV/PRV requirement dataset and FSM database tool to conduct this analysis. The overall accuracy of this analysis could be improved with the inclusion of the other data.

4.8.1 Analysis of the Facility Sustainment Model (FSM)

The purpose of the FSM is to predict annual facility sustainment requirements based on the size of the physical plant at an installation. The FSM is a database management tool that extracts real property information from the ACES-RP database, runs it through the FSM cost factor database that produces the predicted sustainment requirements for each installation. The predicted sustainment levels derived by the FSM are based on historical life-cycle analysis and represent costs spread out over the service life of a facility. Therefore, the annual facility requirements derived by the FSM represent an average based on total expected sustainment divided by the estimated service life of the facility. Actual sustainment costs for these individual facilities will vary significantly from year to year. As a result, the FSM totals should not be used to predict individual facility sustainment requirements; rather the FSM totals should be aggregated across an installation to absorb the cyclical nature of sustainment requirements.

The analysis of the FSM began with isolating the facility requirements of the generic AF installation and then entering that facility inventory into the FSM. The facility specific information was extracted from the ACES real property inventory (which is the FY 2000 PRV dataset). Microsoft Access was used to isolate the specific facility inventory, which included geographically separated facilities in nearby communities. For tracking and reporting purposes, major AF installations will often control the real property of these small facilities or geographically separated installations because those installations do not have the staff to support that level of facility management. Facility funding for in-house or contract sustainment is provided to the major installation from the host MAJCOM and is then distributed to those geographically separated locations as necessary (8).

The next step was to combine the facility specific data with the FSM per unit cost data for each facility classification contained in the DoD Facilities Cost Factor Handbook (17). For example, the DoD Facilities Cost Factor Handbook indicates that the annual sustainment funding for an outdoor swimming pool would $8,072.36/each. By combining the facility information with the cost factors, the FSM returns the total facility sustainment funding necessary for that fiscal year. The results of the calculations are indicated in Table 14. The first column is the overarching facility class that incorporates numerous individual facilities. The second column represents the total predicted sustainment level calculated by using Equation 4 explained in Chapter 2.

Table 14. Generic AFB Facility Sustainment Model Total Requirements

Facility Class	Predicted Sustainment Costs
Operations & Training	$2,530,848
Mobility	$66,746
Maintenance & Production	$1,873,303
Research, Development, Testing, & Evaluation (RDT&E)	$0
Supply	$852,292
Medical	$706,781
Administrative	$1,165,537
Community & Housing	$3,772,865
Utilities & Ground Improvements	$2,629,426
Total	**$13,597,798**

The total predicted sustainment costs for this generic AF installation in FY 2000 was $13,597,798, according to the FSM. This total includes all manpower, equipment, and material costs required for facility sustainment at the major installation and the geographically separated units hosted by the major installation. This model represents a modified square footage formula base model, explained in Chapter 2, and is simple to use, provides a relatively accurate estimate, and is defendable because it is based on industry standards. The FSM total for this generic installation would be combined with other installations in a MAJCOM and then the entire AF to determine the necessary facility sustainment funding required for FY 2000. During development of annual DoD budget, this requirement has been isolated and funds are typically appropriated specifically to the sustainment requirement. Funding is provided to the MAJCOMs and eventually reaches the installation. Ideally, all $13.6 million would eventually be provided to sustain the generic installations facility inventory.

4.8.2 Analysis of the Facility Investment Metric (FIM)

The purpose of the FIM is to objectively advocate the mission impact of facility restoration and modernization requirements. The FIM uses facility project information from the ACES-PM database to develop the results reported in the FIM Mission Area Requirements Matrix (MARM). The FIM Data Tool, develop by HQ AFMC/CEPD, is an Access database tool to assist installations in extracting the FIM data from ACES-PM by ensuring all the data is correct and flagging possible errors that can be corrected prior to final FIM submission to higher headquarters (18). For this analysis though, the FIM IV database already existed, had been thoroughly edited, and was considered complete and accurate. The generic AFB facility requirements were isolated from the FIM IV dataset and a MARM was created, Table 15. The first column of the table indicates each of the four FIM mission areas. The remaining columns are the total facility restoration and modernization requirement totals in each of the mission impact categories; critical, degraded, and enhancement. The final column and final row indicate the totals requirements at the installation in each of the categories.

Table 15. Generic AFB FIM IV MARM for FY 2000

	Impact Ratings			
Mission Area	**Critical Requirements**	**Degraded Requirements**	**Enhancement Requirements**	**Totals**
Primary Mission	$323,000	$1,873,000	$2,718,000	$4,914,000
Mission Support	$2,075,000	$316,000	$13,142,000	$15,533,000
Base Support	$700,000	$3,804,000	$9,088,000	$13,592,000
Community Support	$0	$292,000	$3,245,000	$3,537,000
Totals	$3,098,000	$6,285,000	$28,193,000	$37,576,000

The FIM MARM provides a quick synopsis for decision makers indicating the total facility restoration and modernization facility requirements at an installation level or MAJCOM level. The FIM IV MARM indicates over $37 million in facility requirements at the installation in FY 2000 and identifies the appropriate categories of those requirements. Under the "Critical Impact Rating" for this installation there are the following total requirements: $323,000 in the primary mission area, $2,075,000 in the mission support area, and $700,000 in the base support area. These facility requirements, in order to be classified with a critical mission impact rating, require immediate funding and should be accomplished as soon as possible. In order for a facility requirement to receive a critical rating, it must meet one of the three criteria outlined in Chapter 2.4.3. In this case, there were six critical project requirements within the primary mission category. These requirements directly supported the airfield operations of the installation. If those requirements were not accomplished within the next year, there would be a "significant loss of installation mission capability and frequent mission interruptions."

The FIM tool narrowly identifies restoration and modernization requirements, excluding a wide range of other facility requirements. Narrowing the visible requirements to restoration and modernization does not provide decision makers a consolidated report that gives a complete picture of facility requirements. Some of those excluded requirements include design funds, studies, and projects that are funded from other accounting sources (i.e., MFH, Environmental, Defense Commissary Agency, Defense Energy Supply Center, RDT&E, Medical, Non-Appropriated Funds, MILCON, Transportation Working Capital-Fund, etc.) (12:1). The FIM is too specific to be used as an advocacy tool to decision makers that are not knowledgeable in civil engineering jargon. The FIM is a useful tool for AF civil engineers to use in determining facility requirements, but the results indicated in the FIM should not be articulated to decision makers without additional information. The IRR, on the other hand, does provide a more complete range of facility requirements and will be discussed next.

4.8.3 Analysis of the Installation Readiness Report (IRR)

The purpose of the IRR is to provide objective and timely information to Congress, the DoD, and the AF, on the capability of installations and facilities to support forces in the conduct of their missions. The IRR identifies facility classes that are below minimum acceptable performance in terms of readiness support, as well as the cost to restore facilities to minimal acceptable standards (47:1).

The IRR combines information from the FSM and FIM with other data from MILCON, housing, medical, RDT&E, environmental databases, as well as other sources. MILCON requirements are large recapitalization or new mission military construction projects that are tracked independently from other requirements. MILCON requirements are thoroughly reviewed and are independently approved by Congressional Committees. Housing, medical, RDT&E requirements are reported independently because they are funded by separate appropriations other than O&M. Until recently, environmental requirements were also funded from a separate funding source; however, they are now classified as O&M but are tracked in a different ACES database to comply with regulatory compliance issues.

The information for the IRR for the generic AFB was extracted from the different datasets. The FSM data derived from the FIM IV and PRV datasets, explained in the previous section, was part of the IRR formula calculation. The FIM facility requirements were reorganized into the IRR facility classifications versus the FIM mission areas, and adjusted according to Equation 3 explained in Chapter 2.4.5. There are numerous facility requirements missing from the "Raw Requirements" category of the IRR tool, identified above. Therefore, the raw requirements indicated in Table 16 are not complete. Table 16 illustrates the information from FY 2000 for the generic AFB that is contained in the IRR. The first column indicates the facility class, the second provides the FSM totals, and the third column indicates the total weighted requirements (WR) as determined by part of Equation 6 from Chapter 2, but in this case only includes FIM requirements. For example, the WR for the Operations and Training facility class have requirements in all three FIM mission impact categories. Therefore, using part of Equation 6, the WR equation for the that facility class would look like:

WR = (\$1,529,000 x 5) + (\$1,671,000 x 3) + (\$1,926,000) = \$14,584,000

The fourth column provides the PRV for each facility class. The fifth column is the total of the first two columns or the total weighted requirements (TWR) divided by the PRV to establish the percentage that determines the C-rating. The final column indicates the C-rating for each facility class as determined by all of the data available, where a C-1 rating is minimal impact to mission readiness, while a C-4 rating indicates major impacts.

The IRR does provide the installation commander the ability to adjust the C-ratings up or down by one rating in the "Commander's C-Rating" block (47:8). This allows Commanders to make a management judgment call regarding a facility class's readiness state prior to the information being submitted to higher headquarters. The commanders can consider any supportable data or factors they have to provide a qualitative assessment of their facilities readiness condition. The IRR indicates the calculated C-rating from the model, as well as the adjusted Commanders C-rating. If a Commander deviates from the calculated C-rating, justification must be provided to warrant the adjustment (47:9).

Table 16. Summary IRR Table for Generic AFB for FY 2000

Facility Class	FSM	Weighted Requirements	PRV	TWR/PRV	C-Rating
Operations & Training	$2,530,848	$14,584,000	$319,203,063	5%	C-1
Mobility	$66,746	$150,000	$218,856	99%	C-4
Maintenance & Production	$1,873,303	$4,752,000	$118,817,182	6%	C-1
RDT&E	$0	$0	$0	0%	N/A
Supply	$852,292	$819,000	$38,742,891	4%	C-1
Medical	$706,781	$0	$15,813,491	4%	C-1
Administrative	$1,165,537	$31,026,000	$33,544,219	96%	C-4
Community & Housing	$3,772,865	$18,296,000	$163,322,544	14%	C-2
Utilities & Ground Improvements	$2,629,426	$6,648,000	$243,418,926	4%	C-1

The IRR also indicates how much funding is required from all funding sources, O&M, MILCON, housing, environmental, medical, etc., to improve the C-rating from a C-4 or C-3 up to a C-2 rating. C-4 and C-3 ratings indicate that there are major or significant deficiencies that preclude satisfactory mission accomplishment; whereas C-2 and C-1 ratings are considered acceptable, with only some or minor deficiencies. Installation programmers have the capability to evaluate all of the requirements independently to determine which ones, given the requirements mission impact ratings and funding availability, should be accomplished to raise the C-rating to a C-2. There is no clear indication, within the IRR format, that decision makers can identify a particular requirement as critically impacting the mission of an installation.

The analysis of the installation's facility requirements indicates the disparity between IRR C-ratings and the actual mission impact of facility requirements. Table 16 indicates two facility classes with C-4 ratings (major deficiencies that preclude satisfactory mission accomplishment) and the rest are either C-2 or better (facilities are able to perform required missions). The requirements within the two facility classes, Administrative and Mobility, are a combination of FIM critical, degraded and enhancement mission impacting projects. There were four FIM critical mission impacting requirements within the Administrative and Mobility facility classes, with a weighted sum of $10,125,000; 18 degraded requirements with a weighted sum of $8,202,000; and 64 enhancement requirements with a weighted sum of $12,699,000. Therefore, the installation would be required to accomplish all of the FIM critical (4 projects) and degraded (18 projects) mission impacting requirements, and still have a C-4 rating (41%) because of the $12,699,000 enhancement requirements. Since the AF has been instructed to buy down requirements in order to reduce the C-rating to C-2 or better, the installation would be directed to fund FIM enhancement requirements in the Administrative facility class before FIM critical and degraded requirements in the other facility classes. The Maintenance and Production facility class has one FIM critical and three degraded mission impacting requirements with a weighted sum of $3,298,000, that could be overlooked because the IRR C-rating is a C-1. Therefore, the IRR C-ratings need to be adjusted to eliminate this possible misconception and proposed improvements are fully explained in Chapter 5.

4.8.4 Summary of Complex System Analysis

The AF uses a complex system of reporting tools and a vast information management database to track facility requirements. These tools do not articulate the same requirements in the same terms. The AF methods for managing facility requirements are a complex web of different reporting tools that should be kept within the confines of those personnel that understand the system. Strategic decision makers outside the normal facility management perspective do not need to be inundated with the results from these different reporting tools. AF Civil Engineering needs to develop a single advocacy tool that portrays the physical plant condition and necessary facility requirements without a lot of CE specific jargon. Use of multiple reporting tools adds to the possibility of confusing decision makers and reduces facility manager's credibility in advocating for facility requirements. Recommendations for improving the integration of these reporting tools and possibly consolidating all information into a single advocacy tool are presented in Chapter 5.

4.9 Summary of Results and Analysis

This research analyzed the different methods the AF uses for facility management in an attempt to develop a predictive model to estimate facility restoration requirements as well as provide recommendations for improving the AF methods. The extensive research into the AF methods for managing and reporting facility requirements resulted in several recommended improvements to the ACES database. This research also identified that stepwise regression analysis would not provide a significant predictive model given the data contained in the FIM and Physical Plant datasets. Finally, through a complex system analysis, several recommendations are put forward in the next chapter to improve the integration between the different AF facility requirement reporting tools.

V. CONCLUSIONS AND RECOMMENDATIONS

This chapter provides a review of the research questions and a short summary of the associated findings. Next, conclusions drawn from the research will be presented, accompanied by a presentation of the limitations of the research effort. Finally, recommendations for further research will be presented.

5.1 Research Results

There were three research objectives poised in Chapter 1 that dealt with the improvement of the FIM reporting tool, use of the FIM and PRV information to develop a predictive model for restoration requirements, and improvement of the overall integration of the different advocacy tools used by the AF. These objectives focused the research and subsequent methodology that culminated in the final results presented in Chapter 4.

5.1.1 Overall Findings

There were three main findings discovered during this research: 1) the ACES real property (ACES-RP) and project management (ACES-PM) databases can be improved to include more descriptive variables that will aid future analysis, 2) the use of stepwise statistical regression analysis did not produce an accurate or significant predictive model for estimating restoration requirements using historical FIM database information, and 3) there are areas of the FIM and IRR tools that can be adjusted to improve the overall integration and ability to communicate requirements to decision makers.

5.1.2 Improvements to ACES in Supporting the Reporting Tools

This research identified possible improvements that can be made to the ACES database that will improve the quality of the analytical capabilities of the reporting tools. The adjustments to the ACES database will improve the overall quality of the information contained in the database as well as the ability to run detailed reports for analysis. Several of the ACES-RP fields need to be adjusted to be more descriptive in nature as well as new fields created in the database.

The Real Property Construction Type Code is the first variable that can be improved. The variable is descriptive when it comes to pavement types, but is very generic when it comes to facility construction types. Recommend that the possible field inputs be adjusted to include the following construction types for facilities: brick structure, concrete structure, wood framed structure, etc. These more descriptive facility construction type codes should follow industry standard facility construction type classifications, making them more universally understood. By doing this, it will allow a more detailed analysis to be done on the causal relationship between the type of facility construction materials and the restoration costs that type of facility can expect in the future. Differentiating between the construction types will help to determine if one construction type requires more or less future restoration funding than another construction type. This would be useful to installation decision makers and may direct them to choose one construction type over another depending on the analysis of the data. The construction type, though, is often dependant on the regional climate associated with an installation, which should also be tracked more closely in the ACES database.

The ACES-RP module should include a field variable that indicates the average climate for the installation area. Using the State/Country Code in the ACES-RP database is not an accurate variable, often the climate is the same from state to state or country to country, yet by using this variable, the climates are noted differently. Recommend the use of a "climate index" as defined by the Global Warming Notes Homepage: "the Climate Index is the mean of several climate change indicators. These indicators, such as the frequency of extreme temperatures and heating degree days, are quantities that tend to be noticed by people and have economic significance. In forming the Composite Index, each of the major categories (for example Degree Days) has equal weight. Within each category the subcategories (for example, Heating Degree Days and Cooling Degree Days) receive equal weight" (24:1). This is merely an example of a climate index and the AF should use a standardized index that has a range of values but can be applied across the globe for proper analysis.

AF facility managers are not adequately accounting for the large infrastructure systems at installations. These infrastructure systems on an installation include electrical, potable water, wastewater collection, communications, roadways, and fuel distribution. The ACES-RP module does not properly account for these systems with given facility numbers. Often, when these infrastructure systems require sustainment or restoration work, the requirements are inputted into the ACES-PM module with the facility number of the nearest facility to the system. Installation real property managers need to divide these large infrastructure systems into manageable sections that can be tracked with independent facility numbers. Some installations have gone to this type of system, but most installations in the AF still do not adequately account for these systems.

Although it is important that the quality and descriptive nature of the variables is improved, it needs to be mandated that installation programmers and real property specialists update and maintain the information in the ACES database. Currently, there are fields that could have been used for a more descriptive analysis, but those fields are not mandatory entries and often are overlooked when installation personnel conduct updates. The fields may have provided significance during regression analysis if they are kept current and accurate. Once all of the fields of possible significance are determined, guidance will need to be issued by the ACES program manager that those fields are mandatory entries.

The ACES database is an extremely large and complicated information management system. Each module serves a different segment of an AF Civil Engineer organization. Many of the personnel are trained on specific ACES modules that pertain to their respective job skills, but personnel hardly ever receive training on the other modules. Information contained in the other modules may be critical to management analysis of work processes, but without proper training, facility managers often overlook the services and information the other modules can provide. Additional training into the basics of the other modules will greatly assist all personnel in maximizing the capabilities of the ACES database as a facility management tool.

5.1.3 Results of the Development of a Predictive Model

The main effort of this research determined that a predictive model to estimate facility restoration requirements cannot be accomplished using statistical regression analysis using the information contained in the ACES database as extracted by the FIM and PRV datasets. The results can be examined for possible areas for improvement.

There is extensive research in the area of developing a predictive model for estimating sustainment requirements, but this was the first attempt to develop a predictive model to estimate facility restoration costs using similar methodology. A predictive model to estimate facility restoration requirements may be possible, but significant improvements in the descriptive nature of the variables are needed and possibly a different approach other than stepwise regression analysis.

The use of regression analysis in this research did identify several possible facility variables that provide the most causal relationship with predicting restoration requirements. If the improvements outlined in the previous section are accomplished, the methodology in this research may be tried again to determine the possible positive improvement. The order of significance determined during the research does provide some insight into how important the different variables are and if effort should be put forward in keeping those variables accurate or improving the descriptive nature of the variables. The order of significance was:

1. Plant Replacement Value (the current cost to replace a facility given current construction and facility standards)
2. Real Property Area Amount (the size of a facility or infrastructure system, usually measured in square feet, linear feet, or square yards)
3. Real Property Inventory Control Variable (indicates the macro use of a facility, whether it is a single purpose, multi-purpose, utility, etc.)
4. Real Property Type Construction Code (a descriptive variable that indicates the main construction material of a facility or infrastructure system)

5. Facility Age (indicates the overall age of a facility since initial construction or major renovation)

These findings correspond with the literature in the field of facility sustainment, as these same variables were expected to hold some significance. However, the last facility variable was expected to provide much more significance (high R-square value) than the results indicated. The facility age variable, which the research literature indicated as being significant in estimating sustainment requirements, was not significant in predicting restoration requirements. The results across the five years of facility requirements indicate that the facility age variable is not a good indicator for estimating restoration requirements. One conclusion from this can be that the facility age variable may not be important to future analysis and efforts to keep the variable up to date may not be as critical as efforts to keep other facility variables current and accurate. There are also other variables that should be included, like a climate variable, to assist in further analysis.

There are several factors that may have contributed to the low level of significance determined in the regression analysis. However, all of the possible reasons illustrated below are not included in this analysis and would require additional research to determine the possible additional significance they may provide.

All AF installations do not provide a standard level of sustainment. The main factor is that each MAJCOM has a different philosophy regarding facility sustainment; some MAJCOMs focus on installation infrastructure because their mission is tied to the installation, like missile installations, while other MAJCOMs are focused on the operations of the installation. Installations may have large inventory of facilities that are funding by special fenced appropriations that lends itself to more constant sustainment funding. The sustainment levels also vary due to historic levels of sustainment funding, the backlog of requirements, and the accelerated deterioration because of deferred sustainment or diversion of funds to other areas as deemed necessary by an Installation Commander. If this research is re-accomplished, these variables or similar variables should be left in the analysis to determine the significance.

The low level of significance may also be due to the different operations tempo and level of facility use at different installations. Some bases, because of their operating mission, have higher deterioration rates based on higher use levels (i.e. an operational flying wing with daily operations will deteriorate the airfield much faster than a reserve wing that only flies monthly). Some installations, due to management personalities, perform different levels of sustainment because the decision makers have different priorities that must be considered. For example, one installation may be performing annual preventative maintenance, or full sustainment, while another installation may have a different focus and only perform "breakdown" maintenance, or partial sustainment, that is defined as fixing something only after it breaks. This difference in philosophy greatly impacts the future cost of restoration requirements for each of those installations and the difference in this example can be substantial. Breakdown maintenance may provide short-term funding relief, but often the future costs are substantially higher because the system's service life is considerably less.

The DoD and the AF are implementing A-76 privatization and outsourcing initiatives at numerous installations. One of the key organizations that have been impacted is the installation operation and maintenance (Civil Engineering) function.

There are several outcomes to these A-76 efforts; either the function is determined to be exempt because it provides necessary war fighting skills training, or it is considered a A-76 candidate and goes through the A-76 process which results in complete or partial outsourcing, or the incumbent government organization (Most Efficient Organization) prevails in a much diminished footprint to meet the mandated manpower cuts. Regardless, further research is needed to determine the overall effects of these efforts and how they may affect sustainment and restoration levels at an installation.

There is a research effort underway contracted by the Department of Defense to determine a model for estimating restoration requirements; the contract was awarded to R&K Engineering (32). The results from this research effort may provide some relevant information and insight to R&K Engineering as they press forward in determining if a predictive model is even feasible to estimate restoration requirements given the data that the DoD currently tracks. R&K's research effort may proceed in an entirely different track that explores industry and commercial methods or perhaps even another approach that has not even been considered.

There is a distinct need for a predictive model to estimate facility restoration requirements. The AF currently takes the total restoration requirements in the annual FIM dataset and distributes the amount over the five year planning horizon, depending on the projected O&M funding levels in each of the out-years. This methodology has been used for several years, but has very little credible justification for how much funding is required each year, which contributed to underfunding the facility restoration account for the last several years. An accurate and justifiable predictive model to estimate facility restoration requirements may convince decision makers to begin applying funding to the restoration account to correct those facility requirements.

Regression analysis, given the data currently available in ACES may not be appropriate for developing a predictive model to estimate restoration requirements, however, it should not be ruled out entirely. The framework behind regression analysis is entirely dependant on the quality and type of data that is inputted into the analysis. If the quality or extent of the data can be improved, then additional analysis into the significance of regression analysis should be revisited. It is possible that by improving the quality of facility variables and understanding the sustainment levels of a facility inventory that regression analysis could prove to be accurate in determining facility restoration costs. Additional research into improving the quality of variables, making them more descriptive and specific to current conditions, and determining detailed and accurate ways to estimate sustainment should be explored in an attempt to increase the validity of this approach.

5.1.4 Improvements to the Overall Integration of Reporting Tools

The final focus of this research was to examine the different reporting tools, determine how they interact, and develop recommendations for improvements and better integration. The second question poised in Chapter 1 dealt with this integration issue but was more difficult to determine because it is more subjective depending on how the problem is approached. Beginning with the input of a facility requirement and taking it through the various reporting tools (FSM, FIM, and IRR) exposed some areas that could be adjusted and the overall effectiveness of the tools improved.

When a facility requirement is first entered into the ACES-PM database, all the pertinent project variables are inputted: project number, title, impact rating, programmed amount, and other variables. The ACES-PM database is connected with the ACES-RP database, but when information is transferred to the reporting tools, the ACES-RP information is not accessed and transferred as well. The reporting tools are either Microsoft Access or Excel databases and once the information is transferred, there is no link back to the original ACES database. The transferred information becomes a snapshot in time. Including real property information in the various reporting tools will greatly improve the ability to conduct detailed analysis of the information once it is transferred to the reporting tools. This can be accomplished by adding code to the transfer protocol language or query within the reporting tools so that the pertinent variables are included in the data snapshot.

The FIM reporting tool is very powerful as an advocacy tool for facility requirements when decision makers are determining budgets. The FIM is a detailed database that starts with installation level requirements and can be rolled up to provide a macro perspective at the Numbered Air Force (NAF), MAJCOM or Air Staff level. The tools allow installation commanders to rate each facility requirement independently and assign mission impact ratings that clearly indicate to decision makers at higher headquarters where funding is required or the installation mission may be severely impacted.

The versatility of the FIM tool, though, does not easily address the allocation of funding once appropriated. If funding is provided only to meet the critical mission impact requirements, then installation commanders will recognize this and adjust their ratings to ensure that their facility project requirements get funded. This can be avoided by utilizing the regression model developed during this research or later improved models. Restoration funding requirements predicted by the model would be determined by facility specific information that is entirely objective and would not contain any variables that can be arbitrarily adjusted by the installation, like the mission impact rating. MAJCOMs can take the funding requirements percentage from the model and establish funding levels for each installation under their command. For example, if Langley AFB, through the use of the regression model (see Table 12), determined that their requirements are 5.79 percent of the ACC total facility requirements, then Langley AFB should get 5.79 percent of whatever funding is provided to ACC to complete restoration requirements. The rest of the installations in ACC would receive their percentage as well until all of the funding is exhausted for that fiscal year.

The FSM reporting tool is used to estimate sustainment requirements. This tool uses the real property area amount of a particular facility type and multiplies it by an industry standard cost factor for that exact facility type, further adjusted by a local cost factor. This methodology is a sound approach to estimating and allocating sustainment requirements and should continue to be updated each year. These updates should include revisions to the local cost factor calculations, and the standard cost factors should be adjusted annually to ensure that they are current and reflect adjustments in labor pool costs, material costs, and new technologies.

The IRR tool is used to identify the capabilities of DoD facilities and infrastructure to support forces in the conduct of their mission. The IRR incorporates all funding categories and encompasses all facility requirements at an installation, making it a useful macro level designator to advocate facility requirements. Decision makers, especially those not familiar with the specific jargon of these reporting tools, may find it difficult to make critical funding decisions when confronted with the different reporting tools that interpret the same information differently. The IRR is a tool that combines almost all of the facility requirement information into one macro-level report; however, the way the C-ratings are determined is not appropriate and misleads the decision makers. As indicated in the results of Chapter 4, a facility class can still receive a C-4 rating and only have enhancement facility requirements to be accomplished. This does not meet the intent of the C-rating definitions because the mission is not severely impacted by the current facility requirements. The IRR C-ratings need to be adjusted to correct this misinterpretation of the facility inventory readiness potential.

The IRR needs to be adjusted and used as the primary advocacy tool for decision makers outside the civil engineering arena. Since the IRR is mandated by Congress and controlled by the DoD, the FIM mission areas should be adjusted to match the IRR, but the impact ratings need to remain requirement specific. The IRR C-ratings and the method that derives the C-rating in the IRR need to be adjusted to more closely resemble the FIM mission impact ratings. The current IRR approach has the mission impact rating substantially determined by the number of requirements compared to the total plant replacement value, which does not provide a direct link to mission impact. The mission impact ratings provided in the FIM database are requirement specific and should somehow be translated to the IRR. The weighted adjustment made in the IRR for FIM impact ratings should be abandoned and replaced out-right with a subset in each IRR FAC indicating the total critical, degraded, and enhancement requirements in the FAC.

This may increase the complexity of the IRR matrix, but it will greatly improve the message that the tool is representing. For example, if there are five critical mission impacting requirements in the Operations & Training facility class valued at $1.5 million, then that facility class would have a C-4 rating until all five of those requirements are corrected. Once the critical requirements are corrected, the C-rating would drop to a C-3 rating until the degraded mission impacting requirements are funded and accomplished. If there were four C-rating categories, then the three FIM impacting rating categories would have to be adjusted to match the C-rating impact categories and criteria. The FIM "Degraded" mission impact category could be divided into two, closely aligning with the C-3 and C-2 rating definitions. The purpose of the IRR is to articulate the capabilities of installations and facilities to support forces in the conduct of their missions, and the current C-ratings are not providing an accurate description to decision makers.

Using the USAF IRR C-Ratings by MAJCOM matrix described in Figure 6 of Chapter 2, it is proposed that the revised IRR matrix could resemble Table 17. The major AF commands are across the top row, and the first column represents the nine different facility classes. The second column breaks subdivides each of the nine facility classes into the four C-ratings and the subsequent columns under the MAJCOMs represent the total funding (in millions of dollars) required to correct all of the facility requirements in that particular facility class and mission impact rating. This table would articulate to decision makers the amount of funding required to correct mission critical requirements in each of the facility classes. The main difference between the two approaches is the critical mission impacting requirements are clearly visible in the proposed matrix, while the existing matrix (Figure 6) hides the independent facility requirement mission impact.

The matrix indicated in Table 17 only includes four MAJCOMs and three facility classes as an illustration and would need to be expanded to include all MAJCOMs if implemented.

Table 17. Proposed USAF IRR C-Rating by MAJCOM Matrix

Facility Class	C-Rating	ACC	AETC	AMC	AFRC
Operations & Training	C-4	$4.3	$0.6	$7.2	$0.9
	C-3	$25.4	$15.2	$16.2	$10.2
	C-2	$101.6	$87.2	$84.6	$42.6
	C-1	$46.4	$32.4	$106.3	$26.9
Mobility	C-4	$0.7	$0.2	$17.6	$0.1
	C-3	$4.5	$2.2	$24.3	$2.1
	C-2	$15.2	$7.5	$46.2	$5.8
	C-1	$7.6	$4.2	$32.5	$4.6
Maintenance & Production	C-4	$1.5	$3.2	$4.2	$1.2
	C-3	$14.3	$17.4	$17.2	$7.2
	C-2	$22.9	$14.3	$32.6	$10.5
	C-1	$20.3	$11.5	$27.2	$11.8

5.2 Limitations of the Research Effort

This research effort had several limiting factors already identified in the previous sections. Those limitations included a finite database of only five years of requirement data, a single year of real property data, and the overall data that was used was taken from Air Force databases only. The database tools (Microsoft Access and Excel) used in this research had limited query abilities that resulted in the loss of requirements from the overall analysis due to inaccurate data and stringent matching requirements of the queries. Also, the quality of the variables in the ACES database was a limiting factor and can be improved upon given the recommendations already presented.

During the research analysis phase, many of the variables were adjusted to make them numeric or to generalize a very specific item. The Category Code may be a good field variable to use as representative of the facility use, but when the entire six digit code is used, it dilutes the analysis results. During the research analysis, specifically the adjustment of the PRV dataset, only the first digit of the category code was used as a proxy for facility use. The first digit of the category code puts a facility or infrastructure system into a broad category type, which resembles the IRR facility classes. Category codes that begin with "1" are directly related to operational facilities like airfields, navigation aids, airfield lighting. Further research may attempt to explore increasing the number of digits to two or three to see when the greatest level of significance occurs before the variable is too specific and begins to dilute the overall causal relationship.

One of the most significant limitations during the evaluation of complex systems was the lack of facility requirements from other databases and funding sources like MILCON, housing, environmental, etc. Improvements to these limitations could improve the quality of results determined during this research and are possible areas for future research.

5.3 Areas for Further Research

This chapter includes numerous examples of where databases can be improved, where reporting tools can be adjusted, and where regression analysis may have the capability of producing an accurate predictive model to estimate facility restoration requirements. Once adjustments have been made to the indicated databases, the regression analysis methodology should be attempted again once there is sufficient accurate historic data for analysis. This research, however, indicated that regression analysis may not be appropriate for developing a predictive model to estimate restoration requirements, but a model is still required by the DoD and the AF and needs to be developed. The other military services are also in the process of researching an appropriate methodology to predict restoration requirements, analysis of their approaches may be applicable to the Air Force. Perhaps a different methodology should be used to develop a predictive tool to estimate facility restoration requirements.

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ABBREVIATIONS AND ACRONYMS

ACC	-	Air Combat Command
ACES	-	Automated Civil Engineer System
ACES-PM	-	Automated Civil Engineer System – Project Management Module
ACES-RP	-	Automated Civil Engineer System – Real Property Module
AF	-	Air Force
AFCESA	-	Air Force Civil Engineering Support Agency
AFCESP	-	Air Force Civil Engineer Strategic Plan
AFMC	-	Air Force Material Command
AFSP	-	Air Force Strategic Plan
CMMS	-	Computer Maintenance Management System
CPV	-	Current Plant Value
EEIC	-	Element of Expense Investment Code
FAC	-	Facility Analysis Category
FIM	-	Facility Investment Metric
FMO	-	Furnishings Management Office
FRM	-	Facility Recapitalization Model
FSM	-	Facility Sustainment Model
FYDP	-	Fiscal Year Planning Document
IPT	-	Integrated Process Team
IRR	-	Installation Readiness Report
IWIMS	-	Interim Work Information Management System
MILCON	-	Military Construction
MAJCOM	-	Major Command
MEO	-	Most Efficient Organization
MFH	-	Military Family Housing
NAF	-	Numbered Air Force
PA	-	Programmed Amount
PCMS	-	Project by Contract Management System
PDC	-	Programming, Design, and Construction
PM	-	Program Manager
PML	-	Preventative Maintenance Level
POM	-	Program Objective Memorandum
PRV	-	Plant Replacement Value
QoL	-	Quality of Life
RPIE	-	Real Property Installed Equipment
RPMC	-	Real Property Maintenance by Contract
SME	-	Subject Matter Expert
SRMC	-	Sustainment, Restoration, Modernization by Contract
TWR	-	Total Weighted Requirements
WIMS	-	Work Information Management System

APPENDIX A

Predictor Variables in the Plant Replacement Value (PRV) Database

Each of these data entries represent a possible predictor variable for this research taken from the ACES real property database in FY 2000. The first column represents the possible predictor variable and the second column provides a brief description of what that variable represents. In many cases, the information provided to this research could not ascertain the variable description and HQ USAF/ILE subject matter expert (SME), Mr. Wayne Miller, in most cases indicated that the variable should be disregarded (33:1).

VARIABLE	DESCRIPTION/USE OF VARIABLE
1. MAJCOM RP JRSDCTN	This indicates the MAJCOM with real property jurisdiction over this facility or installation.
2. INSTL LOC INDCTR	Installation Code - four digit code that designates the installation or site, different for every installation.
3. FACT ID NR	Facility number, different facilities at each installation.
4. RP INV CON	Real property inventory control variable - macro level code indicating the use of facility.
5. RP CAT PRES	Real Property category code - provides a very specific facility use designation.
6. BEDROOMS	This would indicate the number of bedrooms available in a facility, specific to housing, not needed for this research.
7. RP H DESG	Real property housing designation - this variable identifies the type of house - enlisted, company grade officer, field grade officer, etc.
8. FILLER	Variable information could not be found for this research, SME indicated to disregard.
9. RP INT	Real property investment code - describes the funding source responsible for the facility construction and continued operation costs.
10. RP TYPE CONSTR	Real property type construction code - macro description of the composition of construction materials of the system or facility.
11. RP COND	Real property condition code - provides a macro level condition assessment such as adequate, substandard, committed for demolition, etc.
12. RP VAC AREA	Variable information could not be found for this

VARIABLE	DESCRIPTION/USE OF VARIABLE
	research, SME indicated to disregard.
13. RP OUTGR LS AREA	Variable information could not be found for this research, SME indicated to disregard.
14. RP OUTGR NLS AREA	Variable information could not be found for this research, SME indicated to disregard.
15. RP AREA AMT	Real property area amount - indicates the size (in specific units of measure) of a facility or infrastructure system.
16. RP OTH AMT	Real property area other amount - often the area amount can be measured using other units for other analysis purposes, this variable indicates the applicable other area amount given the other units.
17. MONETARY VALUE RP	Monetary value of rent paid - rent paid for use of this real property.
18. MONETARY VALUE RR	Monetary value of rent received - rent funding received for use of this real property.
19. EST VAL DON LEA	Estimated value of donated or leased facility.
20. COST GOV	Cost to the government - original cost to the government plus capital improvements.
21. CURR INSTL LOC NAME	Current installation location name - the complete name of the installation
22. CURR INSTL LOC KIND	Current installation location kind - the type of the installation
23. STATE ENTRY ABBREV	State entry abbreviation - four to five digit abbreviation of which state or country where the installation resides.
24. STATE CNTRY CODE	State/Country code - two-digit code indicating which state, territory, or other country where the installation resides.
25. NRST TWN CITY	Nearest town or city - this indicates the nearest town or city to the installation.
26. CONUS OS AREA	Continental United States or overseas area - indicates whether the installation resides in the CONUS or overseas
27. CAT NOMENCLATURE	Category code nomenclature - specific facility use description, matches the category code.
28. MAJCOM RP JRSDCTN 3	MAJCOM with real property jurisdiction 3 - variable indicates which Major Command has real property jurisdiction.
29. CMD TENANT USER	Command tenant user - indicates which MAJCOM that owns the tenant facilities on an installation.
30. CMD TENANT USER COPY	Variable information could not be found for this research, SME indicated to disregard.
31. HOUSE ADEQUACY	House adequacy - rating that describes the adequacy

VARIABLE	DESCRIPTION/USE OF VARIABLE
	of the MFH unit.
32. AREA UOM	Area unit of measure - this describes the unit of measure (square feet, linear feet, mile, gallon, etc.) that corresponds with the real property area amount.
33. OTHER UOM	Other unit of measure - this describes the unit of measure that corresponds with the real property area other amount.
34. YR COMP	Year completed - indicates the year that the facility or infrastructure system was finished constructed.
35. DOD GROUP CODE	Variable information could not be found for this research, SME indicated to disregard.
36. STAT INST	Variable information could not be found for this research, SME indicated to disregard.
37. CY ACT	Calendar year activated - indicates which calendar year the facility or infrastructure system was activated and entered into the real property database since the fiscal year begins prior to the end of the previous calendar year (FY begins 1 Oct).
38. FY ACT	Fiscal year activated - indicates with fiscal year the facility or infrastructure system was activated and begins prior to beginning of the next calendar year.
39. INSTL FNCT	Installation functional type code - provides a macro level indicator of the overall use of the installation, like airfield, depot, missile, etc.
40. TYPE INSTL REAL PRPTY	Type of installation real property - indicates macro level description of installation, like primary, auxiliary, off-base, etc.
41. ERROR CODE	Variable information could not be found for this research, SME indicated to disregard.
42. RENT RECORD 1	Variable information could not be found for this research, SME indicated to disregard.
43. GSA PROPERTY CODE	Variable information could not be found for this research, SME indicated to disregard.
44. USAGE CODE	Designator for the use of the facility, would have been used but could not decipher the numeric code, functional expert not able to supply the code key.
45. LOG PLAN AND REPTNG	Variable information could not be found for this research, SME indicated to disregard.
46. INSTL INDCT PAR	Variable information could not be found for this research, SME indicated to disregard.
47. RP RPLCMNT	Variable information could not be found for this research, SME indicated to disregard.
48. Majcom Credit	MAJCOM that receives the credit for the installations real property

VARIABLE	DESCRIPTION/USE OF VARIABLE
49. RV 97	Replacement value in FY 2000 - current replacement value in whole dollars ($000)
50. RV 97 PACES	Replacement value as derived from the PACES model.
51. PRV 97	Current plant replacement value given the real property record.
52. PRV 97 OPEN	Open base plant replacement value
53. PRV 97 MILCON	Plant replacement value derived from the MILCON model
54. PRV 97 RPM	Variable information could not be found for this research, SME indicated to disregard.
55. RPM PRV	Variable information could not be found for this research, SME indicated to disregard.
56. QoL PRV	Quality of life plant replacement value - if the facility was eligible for QoL funding, the PRV would be indicated here.
57. CY ACT NUMBER	Variable information could not be found for this research, SME indicated to disregard.
58. Original RV 97	Variable information could not be found for this research, SME indicated to disregard.
59. MAJCOM File	Variable information could not be found for this research, SME indicated to disregard.
60. Mission Area	The FIM mission area designation, either PM, MS, BS, or CS.
61. weighted Age	Variable information could not be found for this research, SME indicated to disregard.
62. RDTE Ratio	Variable information could not be found for this research, SME indicated to disregard.
63. MISSION AREA	Same variable as above, the FIM mission area designation, either PM, MS, BS, or CS.
64. PML CODE	Variable information could not be found for this research, SME indicated to disregard.
65. AGE	Facility age since it was constructed or capitally improved.
66. FAC UM	Facility unit of measure - for facilities only, this could be square feet, number of rooms, number of personnel (dorms), etc.
67. FAC Area	Facility Area - this is the amount of the facility unit of measure.
68. MILCON MAJCOM Credit	Variable information could not be found for this research, SME indicated to disregard.
69. MILCON MATRIX	Variable information could not be found for this research, SME indicated to disregard.
70. RPM PRV New	Variable information could not be found for this

VARIABLE	DESCRIPTION/USE OF VARIABLE
	research, SME indicated to disregard.
71. RPM TWCF	Variable information could not be found for this research, SME indicated to disregard.
72. RPM DMAG	Variable information could not be found for this research, SME indicated to disregard.
73. RPM	Variable information could not be found for this research, SME indicated to disregard.
74. MAJCOM Credit RPM	Variable information could not be found for this research, SME indicated to disregard.
75. ACF	Variable information could not be found for this research, SME indicated to disregard.
76. Percent Usage	This indicates the percentage that the primary category code uses the facility.
77. Unit Cost	Variable information could not be found for this research, SME indicated to disregard.
78. RC CODE	Variable information could not be found for this research, SME indicated to disregard.
79. INSTL NAME 40	Installation Name (limited to 40 characters) - indicates the complete installation name.
80. INST NAME	Installation Name - this is the four digit code for the installation.
81. INSTL KIND	Variable information could not be found for this research, SME indicated to disregard.
82. MAJCOM OPRG RSPN	Variable information could not be found for this research, SME indicated to disregard.
83. ST CNTRY CD	State/Country Code - same variable as indicated above, two-digit code indicating which state, territory, or other country where the installation resides.
84. LOC CD	Variable information could not be found for this research, SME indicated to disregard.
85. INSTL CLAS	Variable information could not be found for this research, SME indicated to disregard.
86. STAT INST	Variable information could not be found for this research, SME indicated to disregard.
87. TYPE INSLN REAL PRPTY	Type of installation real property - same variable as indicated above - indicates macro level description of installation, like primary, auxiliary, off-base, etc.
88. INSTL FNCTN	Installation functional type code - same variable as indicated above - provides a macro level indicator of the overall use of the installation, like airfield, depot, missile, etc.
89. STREET ADDR	Street address for the main mail deposit for the installation, from there on it is distributed by AF

VARIABLE	DESCRIPTION/USE OF VARIABLE
	mail personnel
90. DIST TWN CITY	Distance to the nearest town or city in miles
91. DIRO TWN CITY	Direction to the nearest town or city, compass direction.
92. COUNTRY LOC 1	Variable information could not be found for this research, SME indicated to disregard.
93. COUNTRY LOC 2	Variable information could not be found for this research, SME indicated to disregard.
94. CY ACT	Calendar year the installation was activated.
95. FY ACT	Fiscal year the installation was activated.
96. RUNWAY COUNT	How many primary runways does the installation contain, if the installation has a runway.
97. RUNWAY WIDTH	The width of the primary runway in feet, if the installation has a runway.
98. RUNWAY LENGTH	The length of the primary runway in feet, if the installation has a runway.
99. CONT NR	Variable information could not be found for this research, SME indicated to disregard.
100. GSA INSTL NBR	Variable information could not be found for this research, SME indicated to disregard.
101. GSA CITY CODE	Variable information could not be found for this research, SME indicated to disregard.
102. YR 1S REPORTED	Variable information could not be found for this research, SME indicated to disregard.
103. LOG INST CD	Variable information could not be found for this research, SME indicated to disregard.
104. LOG PLAN AND REPTNG	Variable information could not be found for this research, SME indicated to disregard.
105. GROUP CODE	Macro level group code indicating the ownership of the installation.
106. INSTL HISTORY	Variable information could not be found for this research, SME indicated to disregard.
107. USERID	Variable information could not be found for this research, SME indicated to disregard.
108. CHG DATE	Variable information could not be found for this research, SME indicated to disregard.
109. INST OWN	Installation code that owns the requirement to track this facility on their real property records.
110. INST OWN NAME	Installation name that owns the requirement to track this facility on their real property records.
111. MAJ OWN	MAJCOM that owns the requirement to track this facility on their real property records.
112. CLOSE DATE	Date installation closed, 8888888 or 9999999 means the installation is currently still open.

VARIABLE	DESCRIPTION/USE OF VARIABLE
113. OPEN RATIO	If an installation has been partially closed, this ratio indicates the portion that remains own by the AF.
114. ACF	Area cost factor - adjustment factor based on the variable costs of the local area.
115. HNF	Installation name that owns the requirement to track this facility on their real property records.
116. REMOTE NAF	Installation name that owns the requirement to track this facility on their real property records.
117. GOCO	Government Controlled - Contractor Operated facility designation, either yes or no.
118. PLANTS	Installation name that owns the requirement to track this facility on their real property records.
119. MFH CLOSE DATE	Installation name that owns the requirement to track this facility on their real property records.
120. MFH CLOSE	Installation name that owns the requirement to track this facility on their real property records.
121. QDR CATEGORY	Installation name that owns the requirement to track this facility on their real property records.
122. Operations Range	Installation name that owns the requirement to track this facility on their real property records.

APPENDIX B

Adjustments to the PRV Variables

This table indicates the PRV predictor variables that had the possibility of providing some causal relationship to the response variable; however, they were not in a format that allowed statistical analysis. Therefore, the bolded elements of the first column indicate the predictor variables that were chosen, and the remaining descriptions are the possible value descriptions for those main predictor variables. The second column is the value they can be designated in the real property database, and the third column is the value that each variable was changed to for statistical analysis.

Variable Description	**Original Variable Value**	**Adjusted Value**
1. Real Property Inventory Control Variable		
Single Purpose	A	1
Multi-Purpose Summary	B	2
Land	C	3
Multi-Purpose Breakdown	D	4
Other	E	5
Utilities	X	6
2. Real Property Investment Code		
AF Owned, Other than Donated	1	1
AF Owned, Donated	2	2
AF in Lease, Includes GSA Leases	3	3
Permit from Other Agencies	4	4
Permit from other US Military Agencies	5	5
License, Easement, Temporary Land Orders	6	6
AF Owned on Leased Land	7	7
US Constructed on Foreign Land Relocatible	H	8
US Funded Construction on Foreign Land	J	9
Foreign Owned Facility (AF use at no cost by foreign agreement)	K	10
Foreign Owned Land	L	11
NATO Common Infrastructure Funded Facilities	M	12
NATO Common Infrastructure Funded Facilities US Prefinanced	N	13
US Funded Fixed Construction on Foreign Land	P	14

Variable Description	**Original Variable Value**	**Adjusted Value**
Committed to NAT		
Foreign Owned Facilities, NATO Committed (AF use at no cost)	Q	15
Joint NATO and AF use (Cost Sharing)	R	16
3. Real Property Type Construction Code		
Concrete Pavements	4	1
Bituminous Pavement	5	2
Stabilized Pavement	6	3
Other Pavement	7	4
Relocatable Structures and Equipment	8	5
Chemical and Biological Protected Facilities	C	6
Hardened Facility	H	7
Hardened Facility/Biological Facility	K	8
Permanent Facility	P	9
Semi-Permanent Facility	S	10
Temporary Facility	T	11
4. Mission Impact Rating		
Critical Requirement	CRI	1
Degraded Requirement	DEG	2
Enhancement Requirement	MIN	3
5. Mission Area		
Primary Mission	PM	1
Mission Support	MS	2
Base Support	BS	3
Community Support	CS	4
6. MAJCOM with Real Property Jurisdiction		
Air Combat Command	ACC	1
Air Combat Command (Overseas)	ACO	2
Air Education and Training Command	AET	3
Air Force Academy	AFA	4
Air Forces in Europe	AFE	5
Air Force Reserve	AFR	6
Air Mobility Command	AMC	7
Air Mobility Command (Overseas)	AMO	8
Air National Guard	ANG	9
Air National Guard (Overseas)	ANO	10
Industrial	IND	11
Air Force Material Command	MTC	12

Variable Description	Original Variable Value	Adjusted Value
Pacific Air Forces	PAF	13
Air Force Space Command	SPC	14
Air Force Space Command (Overseas)	SPO	15
Air Force Washington	SUW	16
7. MAJCOM Providing Funds		
Army and Air Force Exchange Service	AAF	1
Air Combat Command	ACC	2
11th Wing, Bolling AFB	ADW	3
Air Force Academy	AFA	4
Air Forces in Europe	AFE	5
Air Force Reserve	AFR	6
Air Mobility Command	AMC	7
Air National Guard	ANG	8
Air Education and Training Command	ATC	9
Defense Logistics Agency	DLA	10
	ECP	11
	ELC	12
Air Force Material Command	MTC	13
	OTH	14
Pacific Air Forces	PAF	15
Air Force Special Operations Command	SOC	16
Air Force Space Command	SPC	17
8. Using MAJCOM/Agency		
Air Combat Command	ACC	1
	ACD	2
11th Wing, Bolling AFB	ADW, ESW	3
Air Education and Training Command	AET	4
Air Force Academy	AFA	5
Air Forces in Europe	AFE	6
Air Force Reserve	AFR	7
Air Intelligence Agency	AIA	8
Air Mobility Command	AMC	9
Air National Guard	ANG	10
Bank	BNK	11
Air Force Communication Agency	CMA	12
Credit Union	CRU	13
Defense Commissary Agency	DCA	14
AFELM Defense Accounting and Finance Service	DFA	15
Defense Intelligence Agency	DIA	16

Variable Description	Original Variable Value	Adjusted Value
Defense Logistics Agency	DLA	17
Defense Imagery and Mapping Agency	DMA	18
Department of Justice	DOJ	19
	ELC	20
Engineering and Support Agency	ESC	21
Federal Aviation Agency	FAA	22
Air Force Legal Services Center	LCT	23
Air Force Personnel Center	MPC	24
Air Force Material Command	MTC	25
Air Force MWR & Service Agency	MWR	26
National Aeronautics Space Agency	NAS	27
Non-AF Activities	NON	28
Other Foreign Government	OFG	29
On-Site Inspection Agency	OIA	30
Office of Special Investigation	OSI	31
Other US Government	OUG	32
Other US Air Force Activities	OUS	33
Pacific Air Forces	PAF	34
Other Private Interests	PIO	35
Post Office	POD	36
Air Force Special Operations Command	SOC	37
Air Force Space Command	SPC	38
Air Force Technical Applications Center	TAP	39
Air Force Test and Evaluation Center	TEC	40
Telephone Company	TEL	41
US Army National Guard	UAG	42
US Army	USA	43
US Navy	USN	44
9. Owning MAJCOM		
Air Combat Command	ACC	1
11th Wing, Bolling AFB	ADW	2
Air Force Academy	AFA	3
Air Forces in Europe	AFE	4
Air Force Reserve	AFR	5
Air Mobility Command	AMC	6
Air National Guard	ANG	7
Air Education and Training Command	ATC	8
Air Force Material Command	MTC	9
Pacific Air Forces	PAF	10
Air Force Special Operations Command	SOC	11
Air Force Space Command	SPC	12

Variable Description	Original Variable Value	Adjusted Value
10. Group Code		
US Active	A	1
US Inactive and Under Construction	B	2
US Excess	C	3
US Industrial Active	E	4
US Industrial Excess, Inactive, Stand-by, or Under Construction	F	5
Foreign Active	G	6
Foreign Inactive or Under Construction	H	7
Foreign Excess	I	8
Possessions Active	K	9
Possessions Inactive or Under Construction	L	10
Possessions Excess	M	11
11. Installation Type of Real Property		
Auxillary	A	1
Detached, Other	D	2
Detached, Lease	L	3
Off-Base	O	4
Primary	P	5
12. Installation Functional Type Code		
Airfield	A	1
Non-Airfield Major	B	2
Aircraft Warning Station	C	3
Navigational Aid	D	4
Communication	E	5
Depot	G	6
Depot with Airfield	H	7
Air Force Range	I	8
Air Force Reserve	J	9
Hospital	K	10
Industrial, Government Operated	L	11
Industrial, Contractor Operated	M	12
Non-Industrial, Government Controlled	N	13
Field Test Station	O	14
Missile	P	15
Miscellaneous	Q	16
13. State/Country Code (for climate purpose)		
Alabama	1	1

Variable Description	**Original Variable Value**	**Adjusted Value**
Alaska	2	2
Arizona	4	4
Arkansas	5	5
California	6	6
Colorado	8	8
Connecticut	9	9
Delaware	10	10
District of Columbia	11	11
Florida	12	12
Georgia	13	13
Hawaii	15	15
Idaho	16	16
Illinois	17	17
Indiana	18	18
Iowa	19	19
Kansas	20	20
Kentucky	21	21
Louisiana	22	22
Maryland	24	24
Massachusetts	25	25
Michigan	26	26
Mississippi	27	27
Minnesota	28	28
Missouri	29	29
Montana	30	30
Nebraska	31	31
Nevada	32	32
New Hampshire	33	33
New Jersey	34	34
New Mexico	35	35
New York	36	36
North Carolina	37	37
North Dakota	38	38
Ohio	39	39
Oklahoma	40	40
Oregon	41	41
Pennsylvania	42	42
Rhode Island	44	44
South Carolina	45	45
South Dakota	46	46
Tennessee	47	47
Texas	48	48

Variable Description	Original Variable Value	Adjusted Value
Utah	49	49
Vermont	50	50
Virginia	51	51
Washington	53	53
West Virginia	54	54
Wisconsin	55	55
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14. ABSTRACT

The Department of Defense (DoD) is improving the procedures for identifying, advocating, allocating funding, and accomplishing facility requirements to improve the readiness capability to support the mission. The purposes of this research were to fully explore the methodologies employed by the Air Force (AF) and try to capitalize on industry standard practices to improve the AF methods. Industry has conducted extensive research devoted to the development of predictive models to estimate facility maintenance or sustainment requirements. The DoD and the AF have already implemented the facility sustainment model (FSM) to predict facility sustainment requirements; now however, they are struggling with a justifiable methodology for predicting facility repair or restoration requirements. This research used statistical stepwise regression with historical AF facility requirement cost data for the last five years, in an attempt to develop a predictive model. The analysis results were not significant and did not result in an accurate predictive model, but the methodology and background research did produce some positive results. Observations regarding AF facility requirement reporting tools were identified and recommendations for improved integration were made in the research.

15. SUBJECT TERMS

Facility Maintenance, Facility Repair, Facility Construction, Facility Sustainment, Facility Restoration, Facility Modernization, Infrastructure, Facility Management, Maintenance, Repair, Construction, Sustainment, Restoration, Modernization, Facility Investment Metric, FIM, Facility Sustainment Model, FSM, Installation Readiness Report, IRR, Automated Civil Engineer System, IRR, Facility Recapitalization Model, FRM

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