Balancing Capital and Condition:
An Emerging Approach to Facility Investment Strategy

by

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Abstract

Capital facilities – land and buildings – provide a long-standing environment in which public and private enterprise works, communicates, and thrives. Aligning how facilities "fit" with the dynamic demands of enterprise necessitates continual investment in maintenance, modernization, and development. Conventional tools – condition assessment and master planning – provide a means for measuring this "fit" and producing related investment needs. These tools are often applied independently with a singular focus: condition assessment on physical systems and master planning on sizing and function. The resulting investment needs and condition metrics become fragmented elements of a larger (and often unstructured) investment context that must also consider funding realities and other strategic choices. Exceedingly the methods of collecting and managing assessment data are emphasized, while linkages to capital planning and decision-making remain narrowly focused and limited in scope. The result is simply greater volumes of more "bad news", as facility decision-makers are ill equipped to effectively synthesize numerous requirements and objectively understand the effects of investment decisions.

This research develops and applies a new approach to facility investment strategy. The approach links the products of condition assessment and master planning, as well as ongoing facility costs, within a dynamic capital planning environment, where tradeoffs between present funding decisions and future conditions can be comprehensively explored. Central to the approach is a conceptual framework that integrates investment needs and condition data within a broader planning context. A prototype tool is developed with the aid of information technology as a step toward implementation. The tool employs system-based cost models, aggregated deterioration models, financial-based condition metrics, and other facility cost modeling techniques to estimate present and future investment requirements and facility conditions.

The tool is applied to two real facility portfolios within the U.S. Army Medical Department to demonstrate the feasibility and robustness of developing and evaluating investment strategies that balance capital, condition, and other strategic concerns. The application suggests a new direction for public and institutional capital allocation policy and asset accountability.

Thesis Supervisor: John B. Miller
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Biographic Note

Stephen C. Wooldridge is a Major in the U.S. Army and has practiced engineering since entering active duty in 1992. As a Health Facility Planner in the military, Major Wooldridge has participated in a host of construction related activities ranging from project development and management to capital planning and budgeting.

His military career started at Fort Bragg, North Carolina, where he initially served in the 44th Medical Brigade as an Assistant Operations Officer and Personnel Officer for the 56th Medical Evacuation Battalion. He subsequently served as Brigade Engineer, where he executed both a wartime mission of designing and building field hospital layouts and a peacetime mission of managing and maintaining over fifty support facilities. His following assignment was as a Health Facility Project Officer in the Northeast Region, where he assisted in managing the construction of the $250 million replacement hospital at Fort Bragg.

Major Wooldridge was later reassigned to the Health Facility Planning Agency at the Pentagon, Virginia, where he served as Assistant Director of Construction Management and then as the Chief of Capital Programming, Analysis, and Evaluation. In the former role, he assisted in managing over 35 concurrent works in-progress valued at nearly $500 million. In the latter capacity, he evaluated and recommended capital budgeting priorities for modernizing the Army’s health facility portfolio, which accounts for over 1600 buildings valued at over $8 billion and spans worldwide. He was subsequently selected for an Army Medical Department fellowship to pursue doctoral studies at the Massachusetts Institute of Technology.

Upon completion of his doctoral requirements, Major Wooldridge will move with his wife Jodi, daughters Jacqueline and Hollyn, and son Blake to Heidelberg, Germany, where he will oversee the sustainment, recapitalization, and acquisition of Army health facilities for the European Regional Medical Command.

Chapter 1 Introduction

1.1 Introduction

The central question this research addresses is "How to develop and evaluate financial strategy not only as a portfolio of facilities, but also as a portfolio of investments and condition?" A number of diverse investment requirements are associated with collections of built facilities, ranging from the operations, maintenance, and alteration of existing assets to the development of new assets. Similarly, the concept of condition extends beyond the technical aspects of facilities to include the degree to which they support the activities conducted within – in functional and capacity terms. Developing strategies that balance the array of investment needs and facility conditions is a challenge for owners of collections of facilities, as each investment type responds to different aspects of change that tend to emerge subtly over time. Moreover, facility investments are often inextricably linked to their respective measures of condition, which confounds attempts to understand and determine with any certainty the effects of facility investment. Investment decisions in the built environment are, thus, often fragmented and considered as isolated opportunities, or in some cases neglected entirely.

Investment fragmentation is particularly evident among public and institutional owners. Since the early 1990s, congressional interest has prompted numerous General Accounting Office (GAO) studies describing the impact and scope of under investment and related impeding factors at the federal level. The General Services Administration (GSA) is among those receiving recent attention. Over half of the GSA's 1,682 buildings were in need of repairs estimated at $4 billion. Saldarini (2000a) notes that "GSA's project-by-project mindset still hasn't been replaced with a comprehensive strategic approach..." The Department of Defense, which holds over 80% of the federal government's tangible assets (accounting for some $773 billion in value), has also been cited as not having a comprehensive strategy for sustaining the military service's infrastructure (GAO 1999). The problem goes beyond unmanageable levels of disrepair and unfunded liability. The National Research Council notes the growing proportion of federal buildings in the 40-50 year age range, continued focus on initial capital costs, and increasing numbers of excess and underutilized facilities (NRC 1998). A cycle of concentrated development followed by disinvestment in the recapitalization of facilities is also prevalent among higher education institutions. The number of institutions nearly doubled between the span of the 1950s to the 1970s, and the amount of square feet in-place grew from 600 million to roughly 3 billion (Rush 1990).

Building economics provides a framework for understanding investment decisions in the built environment. As a production good, facilities may be considered part of a capital combination supporting an overall production plan. As these plans evolve and adapt over time to outside economic, social, and political forces, the supporting capital combination must also adapt. Economizing the use and allocation of this capital combination throughout the life cycle of physical resources should therefore be of central concern. However, as Bon (1989) alluded to a decade ago and revisited recently (Bon 1999), building economics overemphasizes the front end of the building process (i.e., initial investment decisions for development). Hence, the investment imbalance evidenced in practice is consistent with the emphasis in research and theory.

Balancing facility investment and the impact it has on facility condition is vital to sustaining the viability of these assets over long time horizons. The continual need to adapt the built environment and to counteract the depreciating effects of obsolescence and deterioration underlies this claim. Recent changes in capital accountability, such as the Governmental Accounting Standards Board (GASB) Statement No. 34 and the Statement of Federal Financial Accounting Standards (SFFAS) No. 6, are attempting to elevate the visibility of the enormous value of infrastructure assets and the significant costs associated with maintaining them. Public and institutional owners at all levels of government are required to account for and report levels of financial commitment and facilities conditions. This mandated transparency, as well as the more practical challenge of managing large collections of built facilities, necessitates a pervasive need for tools and methods that support decision makers in comprehensively balancing investment and condition.

This research develops and applies a comprehensive approach to facility investment strategy. The approach links the array of facility investments within a dynamic capital planning environment, where tradeoffs between present funding decisions and future conditions can be explored at a scalable, portfolio level. Central to the approach is a conceptual framework that integrates investment needs and condition data within a broader planning context. A prototype tool is developed with the aid of information technology as a step toward implementation. The tool employs system-based cost models, aggregated deterioration models, financial-based condition metrics, and other facility cost modeling techniques to estimate present and future investment requirements and facility conditions.

1.2 Motivation

This research is motivated by a practical problem that confronts the U.S. Army Medical Department (AMEDD): "How to effectively invest limited resources across a large-scale portfolio of facilities?" My association with the problem is direct, with nine years of involvement in capital planning and programming for Army health facilities. Resource allocation in this (federal) environment is a competitive process that is influenced by many people with different agendas and worthy goals chasing after too few dollars. The need to understand facility investment requirements and articulate their impact in objective terms is acute.

As stewards of a substantial public investment, roughly $8 billion in replacement value, the AMEDD faces the significant challenge of delivering high-quality health care within a diverse and very complex built environment. Army health care facilities span international boundaries and eras of construction. Facilities range from teaching hospitals, to labs, to small clinics and other supporting facilities. In total, some 35 million square feet of footprint comprise the AMEDD portfolio, which is dispersed across 32 major Army installations and anchored at each location by a large hospital.

Aligning this portfolio with the dynamic landscape of health care practice, innovations in medical and building technologies, and military demographics presents a constant investment challenge. Recent shifts from inpatient care to outpatient care are but one example necessitating a facility investment response. The internal functions, external functions, and capacity demands of facilities are ever changing. Moreover, the physical structures and systems require continual upkeep, which in large part is only deferrable at a significant premium in overall life cycle costs. Many systems within a hospital provide critical life support functions, such as power to life sustaining equipment and medical gases and vacuums to the bedside. Investment needs are as diverse as the Army health facilities. Health care is delivered in buildings that cover nearly five decades of design practices. In Germany, current Army hospitals were previously Nazi headquarters buildings. Several Army hospitals in the U.S. are 1970s vintage "York-Sawyer" designs, which are several story, T-shaped structures that devote a great deal of space to inpatient wards. It is not uncommon to see modern-day medical imaging suites, which are little more than tractor-trailers, affixed to these facilities. There are also two, very large modern medical centers built in the past decade in the U.S. Army inventory.

Understanding the unique needs and demands of this diverse mix of capital assets is a tremendous challenge; doing so continually is an even greater challenge. As part of a proactive life cycle management approach, the AMEDD has effectively employed in the last five years two tools to assist in characterizing facilities and tabulating investment requirements. The first is a comprehensive facility condition assessment that targets the physical fitness of facilities. Condition assessment is accomplished by outside engineering firms. The product of this effort is a detailed summary of the corrective needs and current deficiencies associated with physical systems. The second tool is a master planning process that combines both in-house and outside architectural and health care planning expertise to evaluate the current functional fit of hospitals. The resulting facility master plan lists logically phased requirements that adapt, alter, and upgrade existing buildings. Additionally, this effort recommends the replacement or disposition of existing facilities and the addition of new buildings.

In current form, requirements from both condition assessments and master planning are static, disjointed reams of data that are narrowly linked to capital planning. Each set of data is distinctly channeled. Additionally, ongoing facility costs are not matched and considered with the requirements. Viewing and understanding facility conditions, investment needs, and ongoing costs in a comprehensive manner is recognizably of great value to managing the AMEDD portfolio. However, no organizing structure or tools currently exist to enable this integration and subsequent capital planning efforts. More important, the AMEDD has no supporting tools that assist decision-makers in comprehensively understanding current facility condition and the impact of funding strategies on future condition, while considering other strategic concerns, such as facility replacement policy, pace of investment, facility holding periods, and potential changes to the facility portfolio.

This research takes a step toward filling this void. An extensive review of the literature pertaining to capital facilities planning and infrastructure asset management offers little in the way of practical solutions for buildings. A number of comprehensive asset management systems are proposed or are in use for transportation and are suggestive of linkages to capital planning [see for example Gharaibeh et al. (1999), FHWA (1993), and Zavitski (1992)]. Most of these systems rely on prescriptive optimization solutions for developing capital programs. While optimization may be manageable for pavement and bridges, it is impractical for complex buildings and for strategic level capital planning. A review of the marketplace shows promise for modeling and forecasting physical requirements for buildings; however, linkages to capital planning are limited to system data (the technical aspects of built facilities). Facility condition assessment vendors are developing increasingly more sophisticated information systems for tactical management levels. At a capital planning level, the tools offered focus exclusively on existing assets and do not permit a rigorous investigation of investment alternatives and strategic facility policies.

1.3 Hypothesis & Objectives

The practical need for a comprehensive strategic approach to developing facility investment strategy and the theoretical need to advance beyond the initial stages of the building process are the impetus for this research. The hypothesis of this research is:

> *The combination of capital and condition can provide an essential, objective complement to the array of strategic variables considered in developing and evaluating facility investment strategy.*

An underlying premise of this research is that capital planning (including allocation decisions) is fundamentally a strategic choice problem, not an optimization problem (Miller 2000). At a strategic level, decisions must balance a number of objective and subjective inputs. Quantifiable conditions, costs, and funding are subjected to qualitative pressures, such as politics, traditions, preferences, and conflicting goals. Such factors persistently thrust themselves into the decision environment and thwart efforts at achieving theoretical optimums. Moreover, facilities herein are considered production factors, the combination of which must evolve over time to “fit” current and future demands. A prescriptive solution today is likely short-lived.

The hypothesis implies that some objective information is necessary as a basis of decision-making, if for no other reason than to provide a starting point for negotiation and some measure of outcome for the eventual decision. In this case, the outcomes are those of significance to long-lived assets: measures of condition and levels of capital commitment. These measures provide a basis for systematically narrowing the range of investment alternatives and serve as a stabilizing complement to financial constraints, strategic choices, and other decision pressures. Accordingly, capital and condition furnish a degree of transparency to facility investment decisions.

To investigate the hypothesis, the primary research objectives were:

1) *to develop a practical approach with supporting tools that integrates investment needs, ongoing costs, and condition data and dynamically supports the analysis of alternative investment strategies for a portfolio of facilities*, and
2) *to apply this approach in a real setting, determine its feasibility, and examine its implications for developing and evaluating facility investment strategy.*

1.4 Research Approach

The research objectives were accomplished in five phases, each of which built on a synthesis of theory, fieldwork, and prior experience in capital planning. In the first phase, a conceptual approach for developing and evaluating facility investment strategy was developed, as well as a supporting framework for integrating investment needs. This stage of the research was grounded in both research and practice. An extensive literature review was conducted to understand other approaches to capital facilities planning and asset management and their limitations. Simultaneously, fieldwork related to capital planning was conducted as part of ongoing research in the Infrastructure Systems Development Research group at the Massachusetts Institute of Technology [see for example Garvin et al. (2000) and Wooldridge et al. (2000)]. Additionally, initial concepts were presented to the U.S. Army on separate occasions [see for instance Wooldridge (2001) and Wooldridge (1999)]. Essential features of capital planning from both the literature and fieldwork were synthesized into the final concept, which served as a basis for the remainder of the research.

In the second phase of research, an automated prototype tool was developed for modeling and analyzing facility requirements, financial alternatives, and resulting facility conditions. The conceptual framework developed in the first phase served as a model for structuring the tool. This aspect of the tool relied on cost modeling theory and practices in the U.S. Reference was also made to cost modeling and building economics theory in the U.K. In part, the tool was shaped by the data collection process, which occurred throughout development. The third phase consisted of applying and testing the tool (and approach). Two health facility portfolios from the U.S. Army Medical Department were used as a test-bed for generating and evaluating possible investment strategies. Actual costs and data were used to test realistic strategic considerations. The fourth phase entailed analyzing and evaluating the results of the application. Portfolio investment strategies were developed to explore a range of alternatives that influenced funding, condition, and other strategic choices, such as replacement cycles, acquisitions, dispositions, and pace of investment. The strategies were evaluated in terms of levels of financial commitment and condition. The final phase of the research was to document the results of this research and to specifically address the feasibility and implications of the proposed approach.

1.5 Organization of Dissertation

This dissertation consists of seven chapters and appendices.

Chapter 1 discusses the motivation for this research, the underlying hypothesis, and the research approach taken.

Chapter 2 describes the theoretical foundation for the research and conventional tools for characterizing facility conditions. This chapter emphasizes and explains the conceptual approach and integrative framework and related obsolescence theory.

Chapter 3 provides an overview of the automated prototype tool. Cost modeling and condition modeling techniques are discussed. This chapter also highlights implicit modeling interrelationships.

Chapter 4 presents a background of the application environment. The two application portfolios are described, as well as the scope of their facilities and current conditions. Data collection and initial cash flow variable settings are also discussed.

Chapter 5 develops a number of facility investment strategies based on a practical budget context. The results of these strategies are then presented with a comparative analysis of the disparities between condition and levels of funding.

Chapter 6 summarizes the application of the tool and significant observations made during the analysis. This chapter also evaluates how the tool enables the development of facility investment strategy, limitations of the tool, and the extent of its applicability.

Chapter 7 draws conclusions from the application of the tool and the investigation of alternative investment scenarios. The implications of the approach and future work are also discussed.

The **Appendices** provide a glossary of terms, screen images of the prototype tool, a summary of application data, and detailed funding and condition results for select scenarios.

Chapter 2 Emerging Facility Investment Strategy

2.1 Foundation for Research

The Infrastructure Systems Development Research (ISDR) group at the Massachusetts Institute of Technology is developing a growing body of knowledge related to infrastructure asset management. This group is currently engaged in a long-term effort of developing methods and tools that integrate the disciplines of condition assessment, accounting and budgeting, capital planning, and procurement into comprehensive infrastructure management and decision support systems. These separate disciplines are recognized and treated as "new" variables that can effectively be applied in developing and analyzing value-based strategies for acquiring and sustaining infrastructure systems.

This theory evolved from a procurement perspective. In developing a methodology for selecting project delivery and finance methods, Gordon (1994) concluded that the essential element of the decision was elimination of non-viable methods, rather than choosing a "best" one. He devised a systematic approach for filtering delivery methods based on project and owner characteristics, market conditions, risk allocation, and desired quality of the built product. Concurrently, Miller (1995) investigated nearly 800 federal statutes relating to infrastructure projects and programs dating from 1789 to present, as well as recent infrastructure development strategies employed in Hong Kong. His aim was to understand the extent to which alternative project delivery and finance choices have been applied in the past, are applied currently by other nations, and the role these choices played in shaping infrastructure. A principal conclusion from Miller's work is that continued reliance on segmented delivery approaches (i.e., design-bid-build) and direct public funding is not a viable approach for effectively sustaining and modernizing our nation's infrastructure. Moreover, a long history of leveraging private capital and integrating project delivery (in such forms as design-build-operate and design-build-finance-operate) is indicative of the path forward.

Miller (1997a) subsequently extended these conclusions in proposing a “new” discipline – “engineering systems integration” – that treats project delivery and finance methods as objective variables in the infrastructure management and development process. Rather than viewing procurement and finance as fixed constraints, engineers and planners assemble collections of projects and apply alternative, viable execution approaches to each. Different combinations of delivery and finance choices affect the amplitude and timing of project life cycle costs, which in aggregate must balance with capital constraints. Delivery and finance can thus be varied in a number of combinations to produce financially viable strategies, and life cycle cash flows emerge as a common denominator for evaluation. With the aid of information technology, this new discipline was realized as a prototype decision support tool called CHOICES©™, or Choice of Integrated Civil Engineering System (Evje 1997; Miller and Evje 1997). The CHOICES©™ tool has been applied to several real capital planning situations, including municipal infrastructure (Garvin et al. 2000), quasi-public port infrastructure (Adams 2000), federal military housing, large-scale transportation (Miller and Evje 1999), and many others (Miller 2000).

Application of the CHOICES©™ tool has been complemented by the development of an extensive case study program spanning multiple classes of infrastructure. This program is principled in ten fundamental elements for developing infrastructure strategy (Miller 1997b). Case studies explore the extent to which these principles have been incorporated in numerous real infrastructure procurements. Miller (2000) provides a more current discussion; however, two principles are of particular relevance to this research.

The first – “sound financial analysis over the project life cycle” – recognizes discounted cash flow analysis of life cycle costs as an objective basis for evaluating and comparing alternative development and sustainment strategies. Financially sustainable investment strategies must look beyond initial costs and account for the substantial costs associated with operating, maintaining, and renewing infrastructure assets. Moreover, cash flows reflect choices related to delivery and finance methods and, thus, provide a rational foundation for decision-making.

The second – "scenario building for portfolios of infrastructure projects" – recognizes the significance of considering projects and facilities as a portfolio. Portfolio-based strategy permits a more holistic analysis and evaluation of particular project decisions. Such decisions affect constrained capital, as well as current and future operating funds. Understanding these decisions as a composite provides a broader context for planning. The other aspect of this principle emphasizes scenario-based analysis, which provides a practical method for understanding and comparing the array of real choices and possibilities confronting decision-makers. Multiple variables with uncertain outcomes can be effectively explored with scenarios.

Both principles underpinned this research. The development of a new approach for considering dynamic facility conditions during capital planning is grounded in discounted cash flows of life cycle costs and portfolio-based strategy that employs scenarios as means of evaluation. This work is an extension of the existing and ongoing research of ISDR, principally that of Miller. It is positioned as a precursor to capital programming, where project delivery and finance methods are considered. This research addresses levels of identified requirements (not necessarily packaged as projects), levels of funding (without regard for funding sources), and dynamic conditions (which reflect the disparity between funding and requirements over time). Facility condition is thus treated as an essential guide to establishing funding policies. Investment strategy herein is viewed as that which adequately funds a portfolio of facilities, given known and projected requirements, to maintain desired levels of facility condition over a chosen time horizon. Condition, funding, and timing are, thus, primary planning variables. For a chosen investment strategy, desired levels of funding and requirements become inputs for capital programming, where various mixes of project delivery and finance methods can be explored.

This foundation effectively guided the approach for developing and evaluating facility investment strategy developed in this research. The approach is also supplemented by a comprehensive, yet simplistic, view of facility investment and condition. This view is described in the next section. Common tools for understanding and characterizing facility investment and condition are then described, followed by the essence of this chapter, a section that outlines an emerging approach for developing and evaluating facility investment strategy. Supporting aspects of the approach include an integrative framework for facility investment and an economic basis for comparing and evaluating alternative strategies.

2.2 A Theoretical View of Facilities

A useful context for considering facility investment and condition is provided in the literature related to facility performance and serviceability. The evaluation of facility performance and subsequent related investment can be examined from three general viewpoints: technical, functional, and economic. Schodek (1971) introduced these viewpoints in describing the performance perspectives for evaluating housing systems. More recently, Ang and Wyatt (1999) discussed the significance of integrating these three perspectives in developing a performance concept for buildings in general.

The technical point of view recognizes the physical nature of facilities. That is, a facility is an assembly of many physical systems, sub-systems, and components, which furnish a living and working environment. These physical systems function interdependently to provide, in broad terms, structure, enclosure, internal climate, utilities, and lighting (Reid 1995). The degree to which physical systems perform these functions is largely dependent upon the extent of their operation and maintenance over time. The ongoing operation, maintenance, and repair of systems necessitate continual investment, whether it is in the form of operating or capital funds. Eventually, systems will fail to perform at acceptable levels, fail to perform at all, or simply become obsolete. At this stage, investment is required to renew or replace systems entirely.

The functional aspect of facilities is wide-ranging. For facilities used in the production of goods or services, functionality refers to how well they support the activities and operations of an organization. Externally, the location and siting of facilities are important considerations. The proximity of facilities, to supporting infrastructure, to other organizational facilities, and to potential customers, has a significant influence on the efficiency and effectiveness of operations. Internal to a facility, physical systems are configured and arranged to support different uses and to permit the flow of people and goods.[1] Spatial arrangements and sizes in large part shape the internal activities of an organization. As operational needs evolve and change over time, so the must the physical configurations and spatial layouts, which may involve modifications or additions to existing facilities. Accommodating functional changes over time necessitates further facility investment. The flexibility and adaptability of the internal facility influences the frequency and scope of this investment. The functional lives of a facility are typically less than their engineered counterparts and often necessitate more frequent reinvestment (Ang and Wyatt 1999).

The economic viewpoint refers to the cost of the facility and its impact on the cost of production relative to the benefits that are derived from the facility. In one sense, the economic life of a facility effectively ends when these costs exceed the revenues, profits, or perceived benefits attained from the facility. In another, the economic life of a facility is the period resulting in the minimum annual equivalent cost of ownership (Park and Sharp-Bette 1990). For some organizations, particularly public and non-profit, cost considerations are often the sole determinant of economic life.

This theoretical view of facilities provides a basic framework for considering facility investment and condition. The technical aspects of a facility refer to the physical systems, and the functional aspects pertain to the configuration and capacity of the built environment. Integrating the investment needs associated with each provides a more comprehensive view for understanding the economic aspect of facility strategy. Moreover, the tools used to characterize facilities and investment needs generally align with the technical and functional perspective. These tools are described in the following section.

2.3 Tools for Characterizing Facilities and Related Investment

This section provides a basic familiarity with two tools that are used to identify facility investment needs and condition data. The methods are described briefly with emphasis on the types of requirements that emerge from these tools.

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[1] Slaughter (2001) describes a theoretical framework for understanding the types of functional change

2.3.1 TECHNICAL VIEW : CONDITION ASSESSMENT

Condition assessment is a tool for understanding the current state of facility systems and for identifying requisite maintenance and repairs. It is an integral part of managing physical assets, as it establishes a baseline for evaluating and comparing facilities, identifying deficiencies and corrective needs, and making subsequent investment decisions. It is applied extensively in support of management systems spanning all classes of infrastructure, including pavement, bridges, water, sewer, rail, ports, and buildings (see for example (Saito 1997)). The means and methods of condition assessment vary from infrastructure class to type of owner; however, in general it is a diagnostic process consisting of data collection and analysis. Kaiser (1993) and Kaiser (1989) describe this process for buildings in more depth.

Condition assessment emphasizes the technical aspects of a facility. From a building perspective, it focuses on the deficiencies and repairs associated with physical systems, and corrective needs for bringing these systems into compliance with codes, regulations, and standards. Estimated costs and levels of urgency are typically assigned to these needs as a starting point for budgeting for deferred maintenance and repair. Additionally, condition ratings are often ascribed and used to benchmark relative facilities condition, to trigger maintenance and repair events, and to signal the current state of serviceability and adequacy.

Assessment information is inherently static and requires periodic reassessments and integration with ongoing execution (i.e., project management and maintenance management) systems to maintain its timeliness and value to decision-making. Advances in information technology are closing this gap, as simple databases of the past are becoming more sophisticated and more functional (Teicholz and Edgar 2001). Indeed, the marketplace is growing with engineering service firms offering information management systems with greater degrees of integration and scalability. Assessment information is now being linked to varying degrees with computerized maintenance management systems (CMMS), computer aided facility management (CAFM), and computer aided design (CAD) systems (Kaiser and Davies 2001). At a strategic level,

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within a building and the consequent impact on the interaction of building systems.

these systems remain narrowly linked to capital planning and exclusively focused on existing assets. An online review of 16 different systems [those recommended by Teicholz and Edgar (2001)] and hands-on experience with one [see Fagan (2000)] provide the basis for this assertion. These systems focus on the technical aspects of a facility, and are limited in capability to support comprehensive capital planning.

2.3.1.1 A FINANCIAL-BASED METRIC FOR FACILITY CONDITION

A number of approaches are in use for establishing and presenting the relative condition of facilities (Uzarski and Lavrich 1995). Qualitative descriptors, such as "good," "fair," "poor," and numeric index scales typically represent condition. For example, the U.S. Army uses a color-coded scale for rating the conditions of military installations, where "green" is best, "amber" is fair, and "red" is poor (O'Hara et al. 1997). Uzarski and Burley (1997) established a hierarchical-based approach to assigning numeric indexes to building components, which are linked to systems and finally to a building as a whole. The "building condition index" provides a scale from 0 to 100, where 0 is "failed" and 100 is "excellent." Numeric indexes have also been applied to pavement condition and other infrastructure facilities (Shahin 1994). Relative to qualitative approaches, numeric scales provide a more objective rating for comparing and measuring facilities conditions. However, each is limited in the extent to which it directly conveys financial needs and links to capital budgeting.

The National Association of College and University Business Officers (NACUBO) developed a financial-based metric for facilities condition, one that provides the same comparability as numeric indexes, but directly conveys the level of funding required to improve condition. Called the "facilities condition index," this simple metric is the ratio of the total estimated cost of assessed deficiencies to the current replacement value for a portfolio of facilities (Rush 1991):

Equation 2-1 Facility Condition Index

$$\textit{Facility Condition Index} = \Sigma\ \textit{Deficiencies Costs}\ (\$) \div \Sigma\ \textit{Current Replacement Value}\ (\$)$$

The index is dimensionless, as both numerator and denominator are expressed in monetary terms, and thus provides a relative comparison among facilities. It also easily scales from facility to portfolio by simply summing deficiencies and facility values. That is, deficiencies may be summed for a single facility or for multiple facilities. Higher index values represent greater levels of deficiencies (or backlog) and, thus, worse conditions. NACUBO suggests condition ratings based on ranges of the facility condition index, where a value less than 0.05 is good, between 0.05 to 0.10 is fair, and over 0.10 is poor. These ranges are offered as industry guidelines; however, organizations may find different ranges more suited to their unique facility portfolios. The simplicity of this approach and its direct linkage to facility financial needs make it well suited as a building block for developing and evaluating facility investment strategy. In fact, the approach is gaining widespread use among public and institutional owners (DeFranco 2000; Rabenaldt 2000; Davies and Cholakis 1999).

2.3.2 FUNCTIONAL VIEW: MASTER PLANNING

Master planning (strategic facilities planning) is a process of aligning the built environment with organizational needs and missions. This alignment influences the internal spaces and physical configurations of facilities, as well as the external layout of facility campuses. The process is guided chiefly by organizational strategy, which outlines macro goals for the types of services, the desired share of market, the processes for providing services and products, and organizational structure. Strategic goals provide a baseline for understanding the current and future demand for facility space, as well as how that space should interface with the organization. Existing facilities are assessed from a functional view to determine how well they meet these demands. Current space utilization, adjacencies, and locations are among the considerations. Capps (1994) and Westlake (1995) describe the organizational and operational aspects of master planning further.

The outcome of master planning is of significance to this research. The master plan provides alternative schemes for altering and adapting physical configurations and realigning the size of facilities. These alternatives typically account for changes in technology, changes in operational use and function, and other changes, which in whole are indicative of facility obsolescence. The alternatives are represented as capital requirements or projects. For example, the estimated costs of renovating a floor or organizational area within a facility or of adding a new facility to an existing campus are discrete requirements. The master plan typically arranges these requirements in a logically phased scheme for consideration in capital planning and programming.

2.4 Approach to Facility Investment Strategy

A dynamic approach is proposed to leverage the array of investment needs and condition data from condition assessment and master planning, as well as knowledge of ongoing costs, in a context that most affects facilities: capital planning and decision-making. The approach intends to improve and effectively redefine the development and evaluation of facility investment strategy by comprehensively considering facilities, investment needs, objective condition measures, and other strategic variables. The essential components of this approach are 1) an integrative framework for comprehensively considering facility investment requirements, levels of funding, and facility condition, and 2) an automated prototype tool for dynamically modeling the interaction of requirements and funding decisions and resulting condition. The framework is described below, while the automated tool is covered in the next chapter.

Depicted in Figure 2-1, the approach is dynamic in the following ways: 1) as a continual process of collecting facility information, exploring investment alternatives,

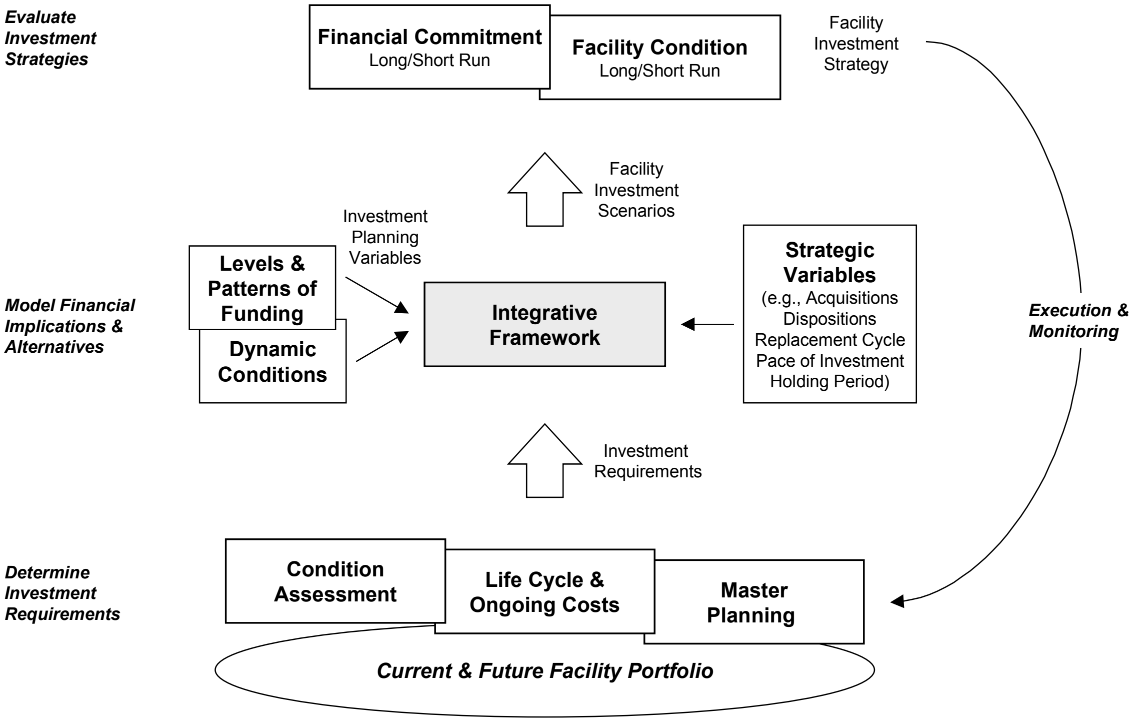

Figure 2-1 Dynamic Approach to Facility Investment Strategy

executing a chosen investment strategy, and updating facility information; 2) as a repetitive decision process based on developing and evaluating multiple investment alternatives; and 3) as a modeling environment that views levels and patterns of funding, facility condition, and the combination of facilities over time. The approach consists of the following four essential processes.

Determine investment requirements. Investment requirements and condition data determined by assessment and planning activities are coupled with ongoing and life cycle costs as a baseline for considering alternative investment strategies.

Model financial implications & alternatives. Investment needs and requirements are structured by an integrative framework within an automated decision support environment. This scenario-based environment allows the facilities decision-maker to explore a number of different investment alternatives by varying levels and patterns of funding. Other strategic variables, such as pace of investment, the acquisition of new facilities (and introduction of new requirements), the disposition of existing facilities (and elimination of existing requirements), can also be introduced. The disparity between requirements and funding is accumulated over time and reflected in condition indicators so the impact of funding decisions can effectively be judged. Life cycle costs for building systems and the growth of backlog are dynamically modeled and incorporated in the requirements. Replacement policies can also be explored by establishing critical levels of backlog and observing the point in time in which those levels are reached. In effect, the decision-maker can create a number of strategic scenarios that reflect varying degrees of real funding constraints and observe the effects of these constraints in terms of facility condition.

Evaluate investment strategies. Multiple scenarios can then be compared and contrasted using levels of financial commitment and dynamic conditions as an objective basis for guiding the decision process. Decision-makers can very clearly understand how each scenario allocates constrained resources and resulting conditions across the entire collection.

Execution & monitoring. As selected strategies are realized through budgeting and project execution, their impacts on condition and investment needs are reflected in baseline data to better inform future planning decisions. Implementation provides a very critical validation of the assessment, planning, and modeling processes used in making decisions.

This research further develops the modeling and evaluation aspects of the approach. However, the approach is proposed conceptually as a complete, dynamic method for consistently understanding built facilities, developing effective investment strategies, and executing and monitoring these strategies.

2.4.1 AN INTEGRATIVE FRAMEWORK

2.4.1.1 INTEGRATING FACILITY INVESTMENT

The integrative framework in Figure 2-2 is the centerpiece for considering facility investment requirements and funding variables within a broad context. The model consists of four primary types of facility investment: *operations*, *sustainment*, *improvement*, and *development*. These four investment types correspond with different life cycle stages of built facilities. The initial conceptualization, design, and construction of buildings is considered *development*, while maintaining and adapting buildings falls into the *sustainment* and *improvement* categories, respectively. *Operations* refers to the ongoing costs of operating a facility. Each of these primary investment types is further divided into secondary classes. The investment classes are among the primary variables considered in establishing a facility investment strategy.

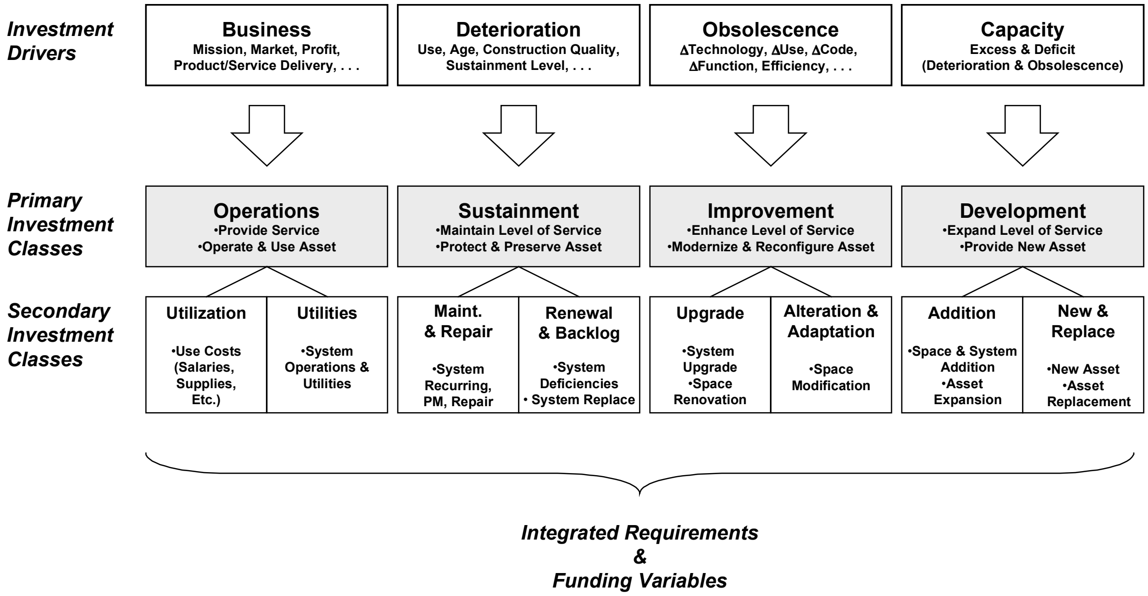

Figure 2-2 Integrative Facility Investment Framework

The framework integrates the disparate investment requirements associated with a facility portfolio and permits the development of funding strategies that balance allocations among these requirements. The framework recognizes the investment required for *operating*, *sustaining*, and *improving* existing assets concurrently with the *development* of new assets. Investment requirements for facilities in place, therefore, temper development and short-term funding views. The integrative framework supports a broad analytic view in recognizing the cross section of life cycle requirements for both existing and new assets to select among alternative funding strategies.

The framework is outlined below by primary investment classes. Associated investment drivers and secondary investment classes are also described within each class.

Operations. Operations refer to the costs associated with operating and using facilities. These costs include utilities costs associated with running facility systems, as well as the utilization costs incurred within the facility. Utilization costs account for personnel salaries, benefits, supplies, equipment, and other costs associated with the activities occurring within a facility. Business motives are considered the main drivers for incurring operations costs.

Sustainment. The objective of sustainment is to maintain the current level of service provided by building systems and space. Sustainment aims to protect and preserve assets from deterioration and absolute loss of utility. Sustainment consists of the ongoing maintenance and repair activities associated with building systems and the ultimate replacement of those systems through capital renewal. The framework treats maintenance and repair distinct from renewal. Maintenance and repair accounts for recurring maintenance activities, such as preventive maintenance, general maintenance, and minor component repairs. Renewal refers to the replacement or substantial repair of systems.

Improvement. The purpose of improvement is to enhance the current level of service provided by systems and space through asset modernization and reconfiguration. Improvement consists of system upgrades, space renovations, and space alterations, which aim to leverage new technology, adapt to changes in use, improve utilization efficiency, and comply with building code changes. These latter factors are indicative of obsolescence and the relative loss of asset utility. The facility master plan assesses these factors and determines appropriate project remedies.

Development. Development adds a new level of building service by expanding existing assets or provides a new asset altogether. Development includes additions to buildings in place, new buildings to accommodate growth, and new buildings to replace those that are beyond improvement. In view of replacement, the disposal of existing buildings also falls in the development category, as both are typically coincident investments. Of course, disposal may generate income through sale or lease, rather than incur disposal costs. Capacity demand is the primary driver for new assets, while deterioration and obsolescence influences replacement. The facility master plan estimates current and future space needs.

2.4.1.2 FACILITY CONDITION INDICATORS

The framework further recognizes facility investment as responses to dynamic cycles of deterioration, obsolescence, and demand for space. Aligning these investment drivers with related investment responses facilitates the development of indicators that are suggestive of investment needs and funding impact. As shown in Figure 2-3, a unique indicator is associated with the primary investment classes to account for the level of deferred investment needs in each class. The technical indicator considers the level of deferred maintenance or recognized deficiencies associated with *sustainment*. The functional indicator accounts for the level of requirements recognized in the *improvement* class, and the capacity indicator recognizes the backlog of *development* needs. Each indicator measures a unique aspect of condition for a facility portfolio, which at any point in time, may be characterized by its degree of technical degradation, functional obsolescence, or need for more capacity.

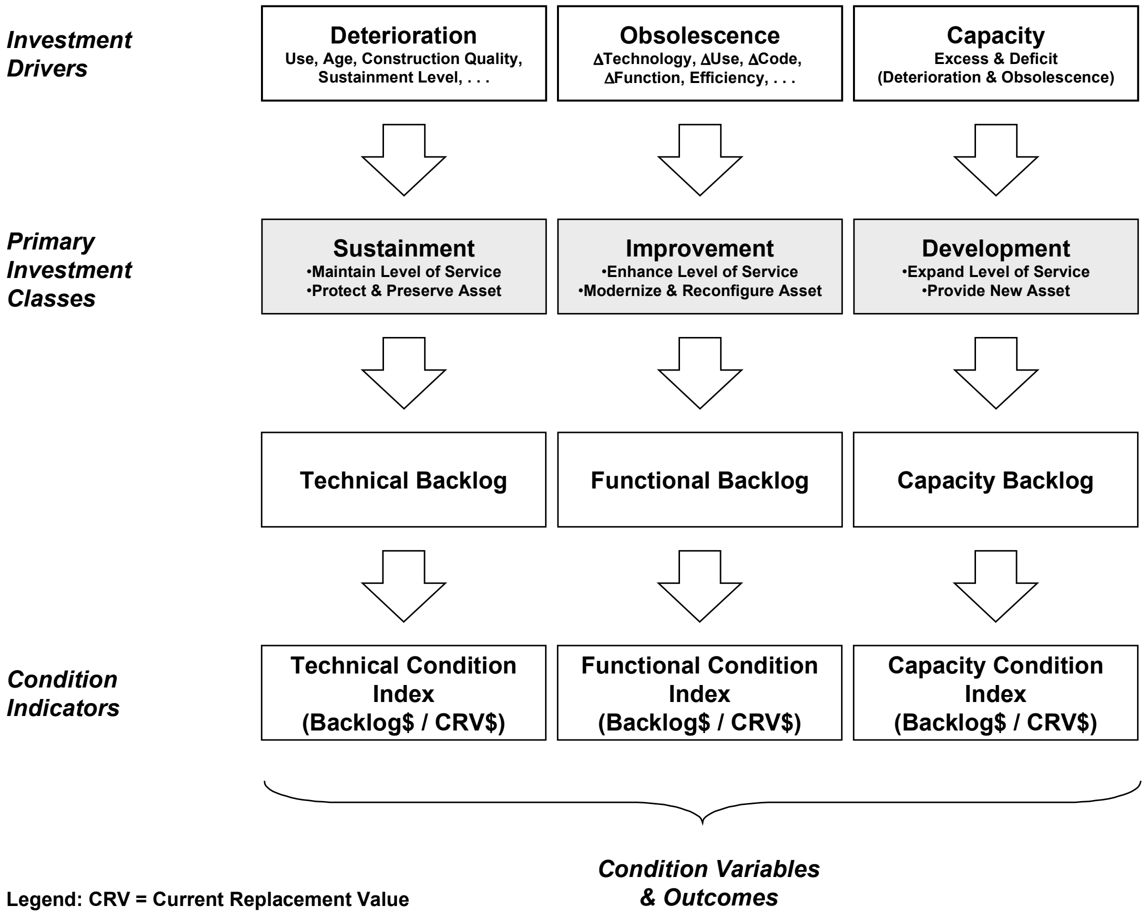

Figure 2-3 Integrative Framework and Condition Indicators

The indicators are modeled as a ratio of the backlog of requirements versus the replacement value of the facility portfolio, similar to the condition metric introduced by NACUBO and discussed in section 2.3.1.1. In this way, the indicators reflect the influence of funding decisions over time as backlog either is reduced or unfunded. To illustrate, consider a facility portfolio valued at $10 million. A condition assessment reveals $3 million in current system deficiencies. A functional assessment has recognized $2 million worth of requirements aimed at reconfiguring and upgrading areas critical to the mission of the organization. The same assessment proposes a $1 million addition to an existing building to account for a severe shortfall in space. The portfolio condition may be characterized using the indicators as the following:

Technical Condition Index = $3 million / $10 million = 0.3;

Functional Condition Index = $2 million / $10 million = 0.2;

Capacity Condition Index = \$1 million / \$10 million = 0.1.

In the following year, \$1 million in sustainment funding is applied to system deficiencies and \$1 million in improvement funding to the functional needs. The capacity indicator remains the same, while the technical condition index is reduced to 0.2 (\$3 million - \$1 million / \$10 million) and the functional condition index is decreased to 0.1.

The condition indicators are thus useful for measuring and comparing the impact of funding decisions over several periods. In contrast, they may be used to determine levels of funding. That is, an organization may effectively set funding policy for its facilities by stating that certain condition indices will remain below a set target value. For instance, technical condition will be reduced to 0.1 for all facilities in a portfolio. The level of funding required to reduce backlog to a level that results in an index value of 0.1 is effectively the organization's facility budget. The indicators are also useful as comparative benchmarks. Consider another portfolio that is valued at \$5 million and carries the same level of technical backlog (systems deficiencies) as the previous portfolio. The technical condition index is 0.6 (\$3 million / \$5 million) and is in relatively much worse condition.

2.4.2 COMPARING AND EVALUATING STRATEGIES

2.4.2.1 PERIOD-BY-PERIOD AND EQUIVALENT ANNUAL CASH FLOWS

Alternative investment strategies are compared and evaluated in terms of cash flows over different time horizons. Funding levels and condition indices are the primary variables and results analyzed, and both are represented by a *pro forma* of cash flows. While funding levels are obvious, condition indices are effectively cash flows as well. Condition indices are ratios of backlog levels to facility replacement values, which are measured in monetary terms and therefore can be treated as cash flows. Funding levels and condition indices can be viewed on a period-by-period basis, which is useful for understanding the dynamics and tradeoffs between these cash flows over time. A periodic view also permits funding outlays to be considered for budgeting purposes. However, comparing, evaluating, and selecting among many alternative investment strategies is not easily accomplished with a simple periodic view.

Techniques that are more economically robust are applied for this purpose. Specifically, cash flows are converted to uniform annual equivalents using basic engineering economics. In this way, multiple cash flows over time are represented by an annual equivalent value that imputes relevant economic assumptions. Annual equivalents are a common method for comparing the cost-effectiveness of investment alternatives with different lives. The annual equivalent method can be considered in two steps. First, discrete cash flows over different periods are converted to a present value (PV) using the following formula:

Equation 2-2 Present Value Formula

$$PV = \sum_{t=1}^{T} \frac{C_t}{(1+r)^t}$$

where, C_t = Cash flow in period t; T = Final period; r = Discount rate

Effectively, the present value is the sum of future cash flows adjusted for the time value of money. That is, the present value is today's worth of all future cash flows. Each future cash flow is discounted by some rate that reflects the degree to which present and future cash flows are weighted. A higher discount rate emphasizes present cash flows more than future cash flows, while a lower rate considers future cash flows with nearly the same weight as those in present. The second step is to convert this present value into discrete, uniform annual cash flows using the following formula:

Equation 2-3 Annual Equivalent Formula

$$AnnualEquivalent = PV \times \frac{r}{1-(1+r)^{-T}}$$

where the variables are the same as equation 2-2

The annual equivalent represents the stream of level, periodic cash flows invested at some rate to fully recover the present value. Park and Sharp-Bette (1990) and Brealey and Myers (1996) discuss the application and calculation of annual equivalents in further detail.

Annual equivalents provide a robust method for evaluating and selecting among different facility investment strategies. Levels and patterns of proposed funding can be more effectively compared. In addition, the two components of the condition index –

backlog and facility replacement value – can be treated as annual equivalents to provide a single representative value of how well facilities condition is maintained over different time horizons.

To illustrate, Figure 2-4 (Part A.) contrasts three notional scenarios aimed at reducing backlog and improving facility condition. The first scenario improves conditions more quickly, but at a higher index value (worse condition). The third offers the best end-state condition, but at a much slower pace than the others. The second straddles the first and third in both pace and final condition. Over a given time horizon it is difficult to suggest which scenario provides the best overall condition profile on a period-by-period basis (i.e., "Is quicker, lesser improvement better than slower, greater improvement?"). As Figure 2-4 (Part B.) shows, both backlog and replacement value can be reduced to an annual equivalent that accounts for the level of each over a given time frame and the degree to which future values are weighted. Figure 2-4 (Part C.) depicts how an equivalent annual condition index is then calculated and used to choose among the different scenarios. This method provides a unique approach for simultaneously considering several investment alternatives.

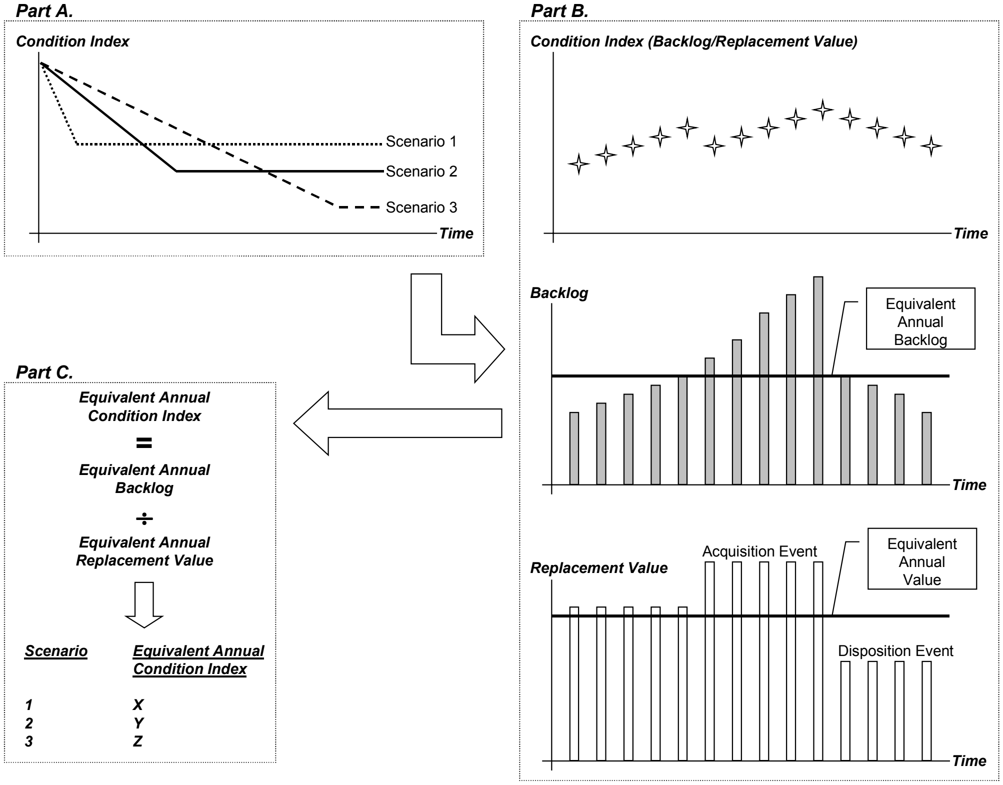

Figure 2-4 Periodic Condition Indices to Equivalent Annual Condition Index

2.4.2.2 REPLACEMENT CYCLE

Alternative investment strategies are also compared in terms of replacement cycle. In capital facilities budgeting, replacement cycle generally represents the ratio of facilities replacement versus the level of annual budgeted funds. For example, \$1 million invested annually replaces \$10 million in asset value over 10 years. In this sense, the replacement cycle represents the supply of capital for replenishing existing facilities. In engineering economics, replacement cycle refers to the economic life of an asset. In other words, replacement cycle is the holding period that results in the minimum cost of owning and operating an asset (Park and Sharp-Bette 1990). In obsolescence theory, replacement cycle represents the end of the useful life of an asset due to deteriorating physical conditions or changing needs in the functionality of a facility.

In this research, replacement cycle accounts for the combination of capital supply and demand, or simply the point at which the condition index reaches a pre-determined threshold value. This threshold value may or may not trigger an actual replacement; however, it does represent a decisive point where replacement may be the only viable option. To illustrate, consider a portfolio of facilities with a given level of physical and functional backlog. Various levels of reinvestment may then be applied to control this backlog. If unattended, the backlog will grow to some level at which it is no longer desirable, for economic or other reasons, to reinvest further. At this point, alternatives may be to replace the whole portfolio or portions of the portfolio, or to dispose of some assets

Chapter 3 Implementing the Approach: A Prototype Tool

3.1 Overview of the Tool

With the aid of information technology, a prototype tool was developed as a means to implement the integrated approach described in the previous chapter. The tool relies on the integrative framework for structuring the array of life-cycle requirements associated with a portfolio of facilities in use. In addition to assets in-place, the tool permits consideration of new acquisitions and, when appropriate, dispositions of existing assets. The tool was primarily designed to assist facilities decision-makers at a strategic, or capital planning, stage, where the primary concern is estimating levels and patterns of investment necessary for effectively managing a portfolio of facilities. Facilities condition is the means for measuring this effectiveness. The capital planning stage generally precedes capital programming and budgeting, which are activities that match sources of funds with the needs and uses determined by facility assessments and other means. The tool considers levels of investment from a demand perspective and serves as an essential link to these subsequent capital allocation activities that focus on the supply of different types of funds.

The tool is financially based with a focus on facilities cost requirements and the extent to which these requirements are funded. In this sense, funding is a primary variable for investigating facilities investment alternatives. Moreover, the tool incorporates a financial-based measure of condition, which affords the facilities decision-maker another primary variable. Facilities requirements, funding, and condition are viewed distinctively yet modeled interdependently within the tool. Facilities requirements are forecasted over time and combined with funding and facilities condition, which serve as planning variables. Depending on the degree of budget constraint, either funding or condition may be dependent on the other. When budgets are constrained at low levels, resulting facilities condition may be the dependent variable.

On the other hand, when funding is treated with discretion, facilities condition may be the driver and funding the result.

The tool supports facility investment planning using a scenario-based approach. Facilities requirements are modeled deterministically over time based on adjustable cash flow variables, which include monetary rates like the discount rate, inflation rate, and growth rate of backlog. The uncertainty of forecasted requirements might then be accounted for with alternative scenarios that impute different modeling assumptions. More importantly, the primary planning variables may be used to generate multiple "what-if" scenarios that allow the facilities decision-maker to consider a range of future facilities conditions based on various levels of financial commitment. The tool saves and aggregates these scenarios and graphically facilitates the comparison and evaluation of each.

The tool is decision oriented, as it comprehensively structures and packages financial information pertaining to a facilities portfolio and enables the decision-maker to consider a range of forecasted changes to that baseline information. As Figure 3-1

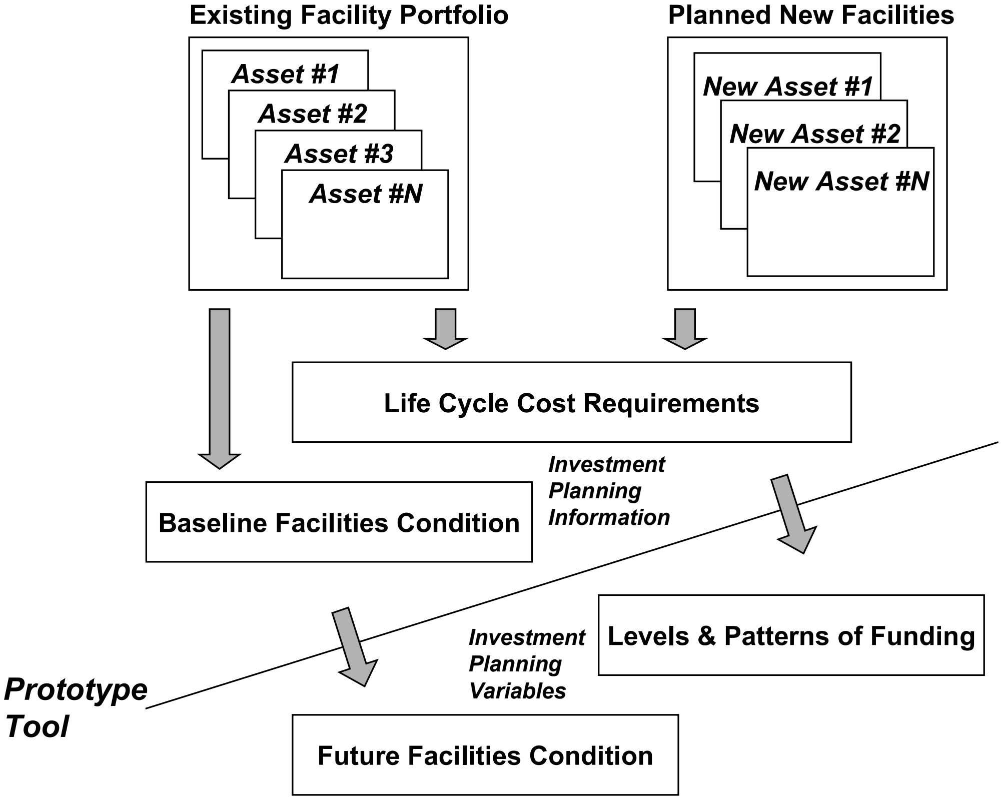

Figure 3-1 Linking Facilities Information to Investment Decisions

illustrates, the tool provides the means for linking facilities information to facilities planning and decision-making. The tool facilitates the assimilation of life cycle cost requirements and baseline condition data and carries out the mechanics of generating future cash flows and condition states, so that the planning effort can focus on exploring viable investment alternatives. The tool aims to augment the judgement of the decision-maker by converting current facilities information into potential outcomes using condition and funding as the principal change drivers. Hence, it may be considered a planning advice tool for facilities decision-makers contemplating the tradeoffs among present conditions and future investments and liabilities.

With this brief introduction, the remainder of this chapter provides a more thorough description of the tool. A conceptual overview of the tool is discussed initially, focusing on overall structure and development. The tool description is further refined in terms of its three main composing parts. Actual screen shots and other supporting details are provided in Appendix B. The tool is then described from a cash flow modeling perspective. General modeling considerations are explained, as well as the specific techniques and supporting theory for each type of facility investment. Next, the methods and theory used to model facility conditions is explained. Finally, the interrelationships among the different facility requirements are discussed. These interrelationships are an important aspect of the implicit modeling assumptions.

3.2 Description of the Tool

3.2.1 STRUCTURE & DEVELOPMENT

As illustrated in Figure 3-2, the tool is composed of three main components: 1) Facility Data, 2) Investment Scenario Modeling, and 3) Investment Scenarios Analysis. The first component provides the basis for organizing and synthesizing the many requirements associated with a portfolio of facilities. This component is used to store and manipulate facilities inventory data, such as, descriptive data, valuation estimates, ongoing costs, systems assessment data and costs, and estimated project costs for recapitalizing existing assets. In addition, planned new and replacement facilities with estimated life cycle costs are included. The facility is the common basis for all data (i.e., requirements are asset-based). However, existing and planned facilities are related geographically and functionally to allow data to be combined at higher organizational levels, such as, by campus, by region, or by multiple campuses spanning a single activity. These asset-based investment requirements provide input for generating multi-year cash flows in the second component.

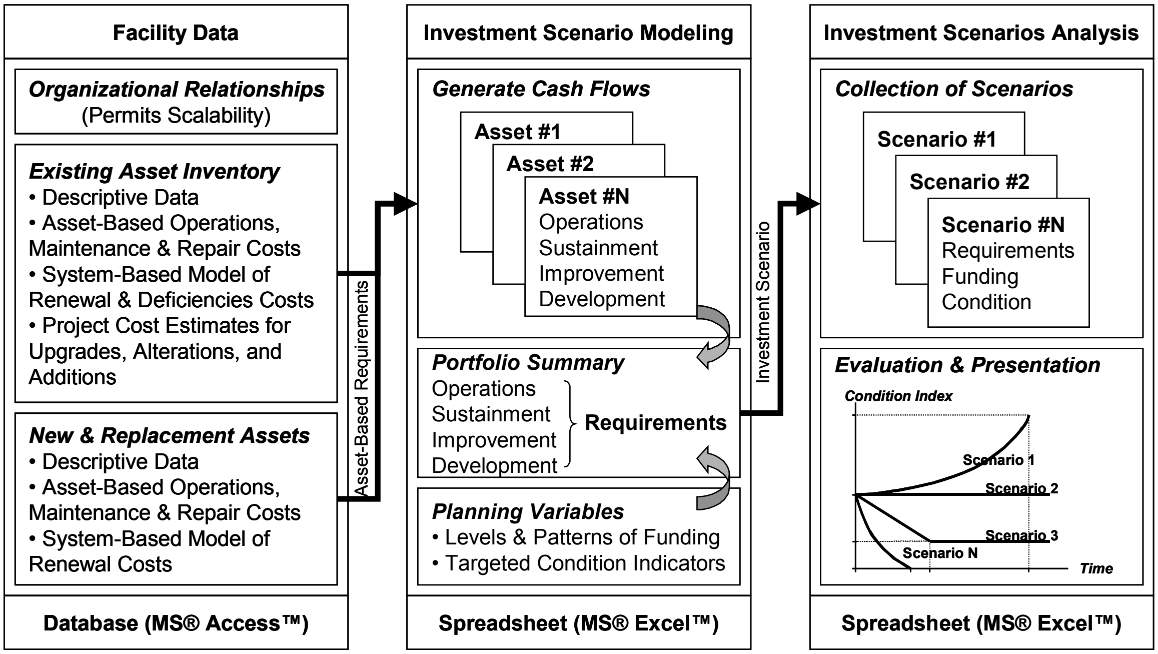

Figure 3-2 Main Components of the Prototype Tool

The second component is the focal point of the tool, as it is used to develop and model alternative investment strategies. In this component, the level of analysis is determined (i.e., either a single facility or multiple facilities is selected) and cash flow modeling assumptions are initialized. Multi-year cash flow requirements are then generated for each facility and combined in a portfolio summary sheet, which also contains funding variables, condition indicators, and algorithms for modeling the interdependencies of each. The entire portfolio of assets can then be comprehensively viewed and various levels and patterns of funding tried to achieve and/or maintain acceptable facilities conditions over time. Other pertinent planning variables, such as, pace of investment, asset improvement policy, and asset replacement policy, can also be considered. The outcome is a candidate investment strategy that is reflective of economic assumptions and facilities policy variables and is represented by future levels of financial commitment and indicators of condition. The tool readily permits an iterative process of developing alternative investment strategies based on different assumptions and planning variables. Each of these strategies is saved in the third component, which combines the results and graphically portrays the outcomes for comparison and evaluation. The three components are described separately in more detail in the sub-sections that follow.

The tool is based in Microsoft[2] Office 97; however, it is also compatible with Microsoft Office 2000 and has been successfully tested in this environment. In current form, the tool is a single-user application built in both Microsoft Access 97 (database) and Microsoft Excel 97 (spreadsheet). Access is the platform used to develop the first component of the tool, while Excel is the development environment for the second and third components. Excel is the engine of the tool, as it generates facility cash flows, performs calculations, and serves as the primary user interface. Development of the tool in Access and Excel parallels that of a client/server application, where in this case, Excel is the client that retrieves data from the Access server. However, in this application, basic data is not changed and updated by Excel (the client) and sent back to Access (the server), so the client/server relation is unidirectional.

An object-oriented programming language, Microsoft Visual Basic[3] for Applications (VBA), is employed extensively to enhance the standard features of both Access and Excel.[4] VBA is used primarily: 1) to provide an enhanced user-interface, 2) to transfer data from Access to Excel using “Data Access Objects” (DAO), 3) to generate multi-period cash flows, and 4) to flexibly save worksheets with pertinent cash flow data in other workbooks, without relying on the frequently unstable “Object Link and Embedding” (OLE) technology that is standard in the Microsoft Office environment. Approximately 2000 lines of VBA code were written in support of the tool.

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[2] Microsoft is a registered trademark of Microsoft Corporation in the USA and other countries.

[3] Visual Basic is a registered trademark of Microsoft Corporation in the USA and other countries.

[4] The use of VBA was essential for development of the prototype tool. Reliance on standard features available in Access and Excel would have restricted the automation of tasks carried out by the tool and limited the degree flexibility currently afforded by the tool. VBA is a relatively simple programming environment, and it resides in the host applications (Access and Excel) as a set of macros. Several good

3.2.2 COMPONENT I: FACILITY DATA

The first component is significant to the overall functioning of the tool, as it organizes and stores facility data for modeling cash flows. As shown in Figure 3-3, this component effectively implements the investment structure from the integrative framework using a relational database. Facility requirements are stored in the tables at the right of the figure. Historical or budgeted *operations* costs are stored in the utilization and utilities tables. *Sustainment* requirements are divided between two tables. The maintenance and repair table collects historical or budgeted costs, and the systems renewal and deficiencies table contains parameters for forecasting renewal costs and estimated costs of current deficiencies. *Improvement* and *development* requirements that are exclusive to existing facilities are stored in the facility project table. This table contains project cost estimates for upgrades, alterations, and additions. A detailed view of these tables with actual data fields is shown in Figure B-1 of the appendix.

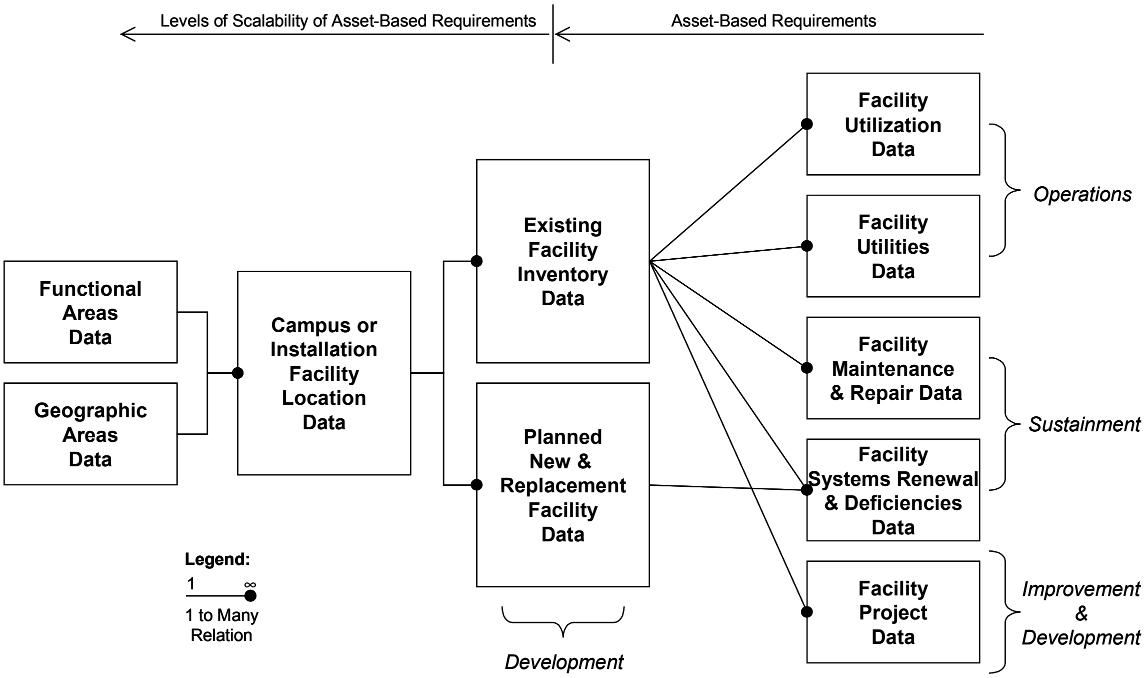

Figure 3-3 Conceptual Structure of Facility Database Component

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references were used to learn and develop the application tool using VBA, including Harris (1997), Sanna (1997), Microsoft (1996a), and Microsoft (1996b).

The requirements tables are related to the facility inventory table (shown by the connecting lines) so that multiple requirements can be consolidated by asset. The facility inventory table contains descriptive data, such as name, size, year built, and type of use, for existing assets. In addition, planned new and replacement facilities are accounted for in a separate table, which represents the other aspect of *development* in the integrative framework. Projected utilities and maintenance and repair costs are included in the new facilities table, which is also linked to the systems renewal table. Hence, asset-based requirements are associated with both existing and planned facilities. Changes to the facility inventory through acquisitions and dispositions can then be reflected in the overall requirements of a portfolio. For instance, a new facility may be planned for replacing an existing facility. Construction will commence three years from now and will last two years. Requirements associated with the replaced facility will thus be eliminated in five years, and the *operations* and *sustainment* requirements for the new facility will be added.

The existing and planned facility tables are further related to a campus (or installation) table that contains location data, such as campus name, state, and zip code. Moreover, the campus table is related to two tables that represent geographic and functional areas. These relations permit the scalability of asset-based requirements from a single campus to multiple campuses located within the same geographic region or serving the same organizational function. For example, facility requirements may be consolidated by campuses located in the Midwest, East, or Southwest. Furthermore, requirements may be combined by campuses whose primary organizational function is manufacturing, sales, or administration. The screen shot in Figure B-2 of the appendix demonstrates scalability in selecting a particular facility from an installation within a region for data entry.

The relational database was developed initially, and concurrently with the collection of data, so aspects of the data are unique to the source and are reflective of that available for this research. However, a majority of the data is standard and generally available among different facility owners of varying sophistication. Examples of standard data include facility name, size, location, year built, and unit-based operations and maintenance costs. Unique data elements relate primarily to the systems renewal and deficiencies table. This data reflects the detailed level of information available from facility condition assessments.

Different owners with varying needs for information will undoubtedly possess a range of assessment and requirements data, from limited to very detailed. The database environment readily permits the modification of data tables to account for such discrepancies. In fact, as Figure B-1 illustrates, the relational database is developed with a number of sub-tables that allow different types of requirements, facilities, and projects to be specified. For example, the user may specify facility types such as, office, warehouse, and academic, to define type of use. The user may also specify different facility systems such as, superstructure, exterior closure, interior finishes, and services. From the perspective of the tool, the most important aspect of the database is that cost requirements are estimated for each investment class (from the integrative framework) at least at the facility level.

3.2.3 COMPONENT II: INVESTMENT SCENARIO MODELING

The second component is the heart of the tool, as it retrieves asset-based data from the database, permits the development of trial investment strategies, and exports viable scenarios to the third for comparison and evaluation. This component is the primary user interface for selecting a level of analysis (from asset to portfolio), initializing cash flow variables, exploring different levels of funding for a set of facility requirements, and reviewing the impact of a chosen strategy. Developed within an Excel workbook, this component consists of a number of worksheets and VBA macros that calculate, store, and compile asset-based cash flows.

Figure 3-4 shows the modeling component in conceptual form. Screen shots are also provided in Appendix B. A form is provided to aid the user in selecting a level of analysis and the specific asset or portfolio to be analyzed (see Figure B-3). Command buttons are used to generate cash flows for the existing facilities and/or planned new facilities. In this way, existing and planned facilities may be considered independently or concurrently. Costs and parameters are then retrieved from the database and converted to multi-year cash flows. Cash flows are modeled annually over 100 years, which covers the renewal of all facility systems, yet allows the evaluation and analysis to occur over shorter, more reasonable horizons. Cash flows are associated with each facility and categorically grouped in separate worksheets based on the secondary investment classes defined in the integrative framework. Figure B-4 shows a sample worksheet with utility cash flows, and Figure B-5 shows a sample worksheet containing renewal cash flows. Other worksheets contain cash flows for utilization, maintenance and repair, and project costs. Each of these worksheets predicts cash flow requirements in constant (or real) terms based on the chosen decision year.

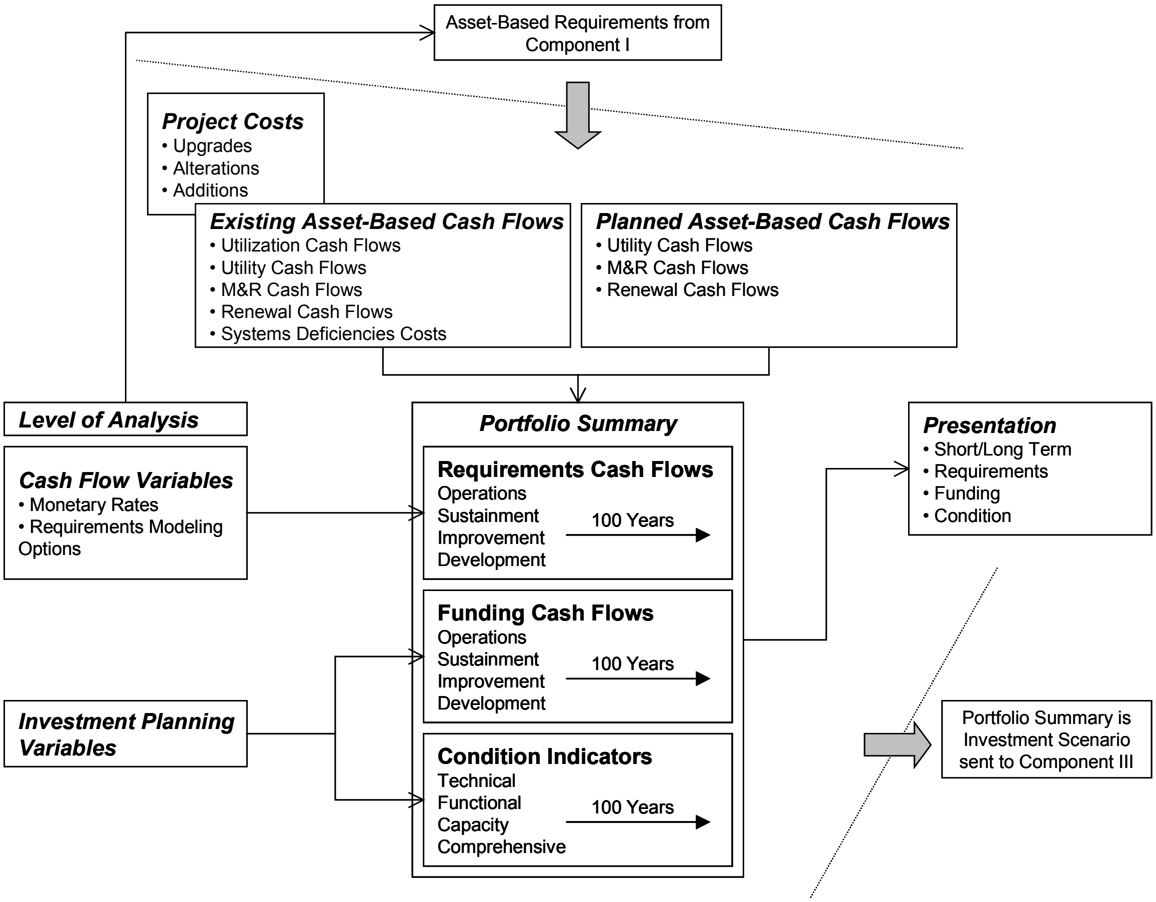

Figure 3-4 Conceptual Structure of Investment Scenario Modeling Component

The cash flows from the separate worksheets are aggregated and linked to the requirements section of the portfolio summary sheet (see Figure B-6). The requirements section represents all identified needs for *operating*, *sustaining*, *improving*, and *developing* a selected facility portfolio. Investment planning takes place in the funding and condition indicator sections. Funding may be set to match requirements as they come due in a given year, or it may be treated as variable levels over time given available sources. Funding is treated as a unique decision for each investment class. For instance, *operations* and *sustainment* funding may be set to match requirements, while *improvement* and *development* is considered with discretion. The condition indicators are used to reflect deferred requirements, and the consequent outcomes of funding decisions. When funding is discretionary, the condition indicators may be treated as variables. For example, the level of funding over time for a given investment class may be determined to achieve a preferred condition indicator value. Excel provides tools, such as "Goal Seek," to facilitate this approach.

Cash flow modeling variables comprise a separate worksheet (see Figure B-7), and they are initialized before adjusting the investment planning variables. The cash flow variables permit separate inflation rates for each investment class. For example, *operations* cash flows can be inflated at a different rate than *sustainment* and *development*. In addition, the system (technical) backlog deterioration rate, discount rate, and replacement threshold may be adjusted. The relation of these monetary rates to cash flows is discussed in more detail in section 3.3. Requirements modeling techniques for maintenance and repair and renewal may also be changed. Maintenance and repair can be modeled based on historical costs or budget methods, such as cost per square foot or percent of value. Renewal costs can be modeled as they are projected to come due, as an average of projections, as a linear trend of projections, or as the uniform annual equivalent of projections. Finally, funding may be set to match requirements or to account for variable levels for each investment class.

Presentation graphs are included in this component to aid the user in visualizing the impact of funding decisions over a short (10-year) and long (25-year) horizon. The graphs portray annual levels of requirements and funding with condition indicators. Figures B-8 and B-9 show screen shots of sample graphs. After a trial investment strategy is developed and deemed worthy of further consideration, it may be saved in the third component for comparison and evaluation with other strategies. The portfolio summary sheet effectively represents the investment strategy.

3.2.4 COMPONENT III: INVESTMENT SCENARIOS ANALYSIS

The third component of the tool collects and stores multiple trial investment strategies for comparison and evaluation. In effect, this part of the tool provides a window for analyzing the tradeoffs between condition and funding decisions among many different scenarios. This component is also developed in an Excel workbook. The portfolio summary sheets from the second component are copied and saved in separate worksheets, and the built-in graphing capabilities of Excel are used to depict scenario results side by side. The essence of this component is collecting the scenarios. The types of graphs and the specific scenarios included in each are easily modified by the user. Examples of the types of comparative charts used in this research are presented throughout chapter 5, which discusses the results and analysis of a real application of the tool.

3.2.5 SCALABILITY OF TOOL

The tool is designed for scalability in a number of ways. It permits a scalable view of facilities, types of investment, and aspects of condition. Asset-based cash flows allow facilities to be treated individually or as a portfolio at any given organizational level. The portfolio levels may include a campus of proximate facilities or a collection of campuses within an organization. Investment is considered in terms of capital and operational funding, which is classified as *operations*, *sustainment*, *improvement*, and *development*. Investment is thus scalable from a total amount to these primary classes, so that alternative strategies may emphasize one type of investment over another. That is, strategies may focus on *development*, rather than recapitalizing existing assets. Alternatively, strategies may focus on the *operation* and *sustainment* of existing assets at the expense of new acquisitions. Furthermore, condition can be viewed comprehensively or in terms of its technical, functional, and capacity elements. In this way, the effect of strategies emphasizing one type of investment can be understood across different aspects of condition.

While primarily intended to support executive planning decisions, the information compiled and presented by the tool may also scale vertically across other management levels. At the executive level, the tool permits the exploration of multiple facility investment strategies and supports subsequent decisions related to fiscal policy. At a financial management level, the tool aids in forecasting more holistic facilities budgets over different time horizons, permits financial scenario planning with an emphasis on potential facility impacts, and accounts for the acquisition and disposition of existing facilities. At an operational level, the tool incorporates project cost estimates aimed at correcting functional and capacity deficiencies by type of space, allowing operational managers to understand how the facility supports their needs comparatively. At a facility manager level, the tool forecasts systems needs and permits effective deficiency management. This comprehensive ability to support multiple management levels, however, is predicated on financial-based information from engineering condition assessments and architectural functional assessments. Consequently, the degree of scalability is dependent upon the level of detail and sophistication of the assessment data. The tool is designed generically to account for owners with various degrees of sophistication.

3.3 Modeling Facility Cash Flows: Techniques & Theory

3.3.1 GENERAL MODELING CONSIDERATIONS

Facility cash flows are modeled deterministically for a given set of economic assumptions. Forecasts of future financial needs, therefore, represent a proposed final state. In actuality, facility needs are more likely to take on a number of possible final states over future periods (i.e., behave stochastically).[5] However, modeling facility needs based on stochastic methods compounds the modeling effort and provides a questionable degree of benefit for the cost of complexity, especially to the decision-maker at a capital planning level. The intent of the tool is to provide reasonably accurate and repeatable results at a minimum level of data overhead, so that the outcome of scenarios reflects changes to the funding and condition variables, rather than changes to the modeled requirements. Moreover, the tool readily permits changes to modeling assumptions and

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[5] There is wide consensus on the stochastic nature of facility cash flows. A majority of the literature on cash flow uncertainty focuses on construction [see Skitmore and Marston (1999) and Brandon (1987) for a representative sample]. However, Bon (1989) describes the inherent uncertainty of adapting and altering assets in-use as responses to dynamic economic events. Moreover, the renewal and rehabilitation of physical systems depends on the notion of predicted service life, which implies the probabilistic nature of forecasting cash flows from a timing perspective.

production of comparative scenarios to account for uncertainty. For instance, the estimated service life of a facility system can be modified, as well as the cost of renewal, and an alternative scenario generated for comparison with a base scenario.

The modeling approach may be classified as descriptive, in contrast to prescriptive models that rely on optimization methods to prescribe a "best" course of action.[6] In this sense, the tool describes the potential impact on future facility requirements given initial assumptions and chosen funding levels. Accordingly, the tool assists the decision-maker in answering questions such as: "If I invest in facilities at this level over this timeline, what will be the facilities condition in this period?" or "If facilities are in this condition today and I want to improve them by this period, how much funding will be required?" As a descriptive model, the tool supports the experience of the decision-maker, rather than replacing it with automation.

The tool in current form models cash flow requirements as shown in Figure 3-5. The overall approach to integrated facility investment and deployment of the tool is predicated on knowledge of the assets in the facility owner's portfolio. In particular, the approach presumes that financial-based data is available for each facility. Historical and project cost data is generally prevalent among facility owners. The degree to which these costs represent the current and future needs of the organization is the most significant challenge to the modeling effort. The greatest difference among owners is the extent to which facility condition assessments are applied and assessment outcomes measured. The tool is built around a financial-based engineering assessment approach that measures costs and conditions by facility system. The following sub-sections discuss the modeling methods in Figure 3-5 in more detail. All requirements are treated as discrete cash flows on an annual basis.

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[6] ReVelle et al. (1997) describe the classification of mathematical models in more depth. Their explanation of systems analysis provides a table of mathematical models arrayed by prescriptive and descriptive models on one axis and deterministic and stochastic models on the opposing axis.

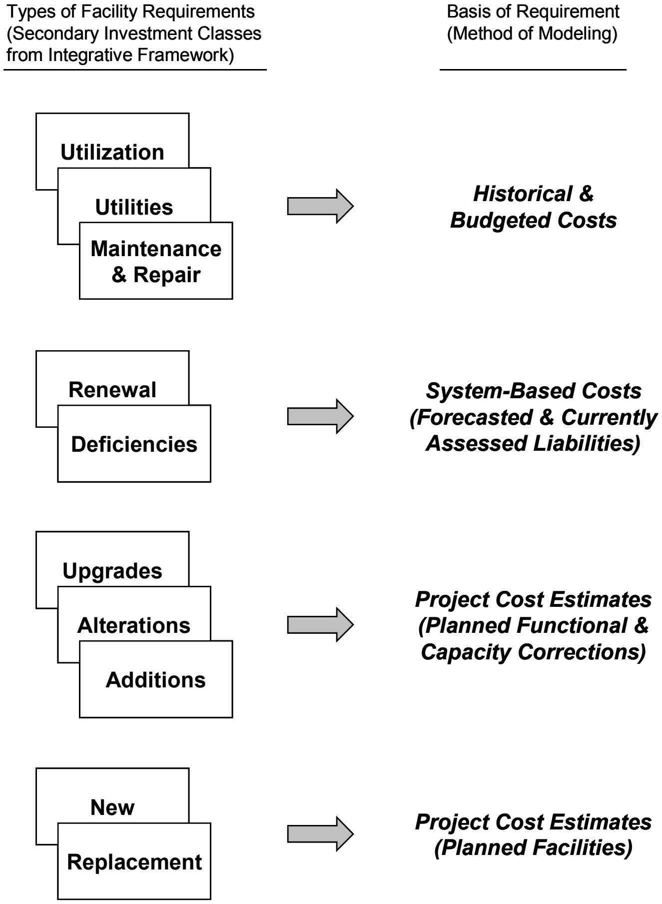

Figure 3-5 Facility Requirements and Modeling Methods

3.3.2 HISTORICAL & BUDGETED COSTS

Utilization, utilities, and maintenance and repair requirements are modeled based on available historical or budgeted costs. The database component of the tool is structured so that each of these cost categories can be considered as detailed sub-costs, such as salaries, supplies, electric, steam, water, maintenance staff, and maintenance contracts. However, they are totaled by facility in the modeling component of the tool (e.g., total utilities costs per facility per year). Utilities and maintenance and repair costs for new assets are modeled by a unit cost factor that is derived from the historical costs of existing assets. The unit cost factor is multiplied by the size of the proposed facility to estimate a total annual cost. Costs are projected in constant terms and are inflated in the portfolio summary worksheet. The spreadsheet environment readily permits these real costs to be forecasted using any number of techniques, including regression, moving averages, or other methods. Furthermore, single period changes can be easily made to account for one-time events, such as removing a facility from the portfolio.

In effect, forecasts based on historical data implicitly assume that past expenditure was adequate and representative of facility performance policies and standards. This assumption may be faulted, since historical data may simply represent the availability of funds (the supply) rather than the actual demand for funds. Balta (1984) discusses this implication from the perspective of maintenance planning, noting that historical based models are insensitive to changes in maintenance policy. Furthermore, historical-based forecasts perpetuate incremental budgeting, which over time diverge from actual requirements (Barco 1994). On the contrary, historical data is in general a practical source and may well represent actual needs, particularly if more sophisticated budgeting practices (i.e., zero-based or program budgeting) are in place [see (Wooldridge et al. 2000) for an explanation of these budgeting practices]. Christian and Pandeya (1997) relied on historical utilities and maintenance costs in developing cost prediction models for a facility management decision support system and concluded that the predictive models were imprecise but beneficial for planning purposes. A historical-based modeling approach was chosen for utilization, utilities, and maintenance and repair costs as a matter of practicality. Although potentially imprecise, this approach is assumed generally accurate and feasible for the purposes of the planning tool.

The tool provides two alternative approaches for modeling maintenance and repair requirements. The first is based on unit cost, and the second is value-based. Both are commonly employed budgeting methods that simply require square footage or plant replacement value for calculation. Ottoman et al. (1999) discuss the extent of use and criticisms of these methods. Numerous studies have suggested appropriate rates for both approaches. Ottoman et al. (1999), Barco (1994), and Bromilow and Pawsey (1987) summarize sources and rates for value-based methods, which range from 1% to 4% of plant replacement value. Unit cost rates vary by facility type, among other factors, and are available from published benchmark studies.[7] It is important to note that facility

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[7] The International Facility Management Association (IFMA) publishes *Operations and Maintenance Benchmarks*, and the Building Owners and Managers Association (BOMA) publishes the *Experience*

systems renewal is treated distinctively from maintenance and repairs in the modeling tool, so the selected rates should be adjusted accordingly.

3.3.3 SYSTEM –BASED COSTS

Renewal and deficiencies requirements are modeled using a life cycle approach that considers each facility as a composition of system assemblies. Life cycle approaches have long been recognized for facility maintenance budgeting purposes. Such methods have been employed at a macro level using actuarial-based formulas that depend on a relatively small set of descriptive facility parameters [see for example Phillips (1989) and Sherman and Dergis (1981)]. More detailed life cycle approaches model the characteristics of individual facility systems [see for example Kaiser (1994), Neely and Neathammer (1989), Neely (1986), and Biedenweg and Hutson (1984)]. A criticism of the formula approaches is that they fail to account for system condition (Stahl 1997), which affects cost-time profiles. In addition, there is debate about which facility parameters (e.g., size, age, use, and value) are more representative of renewal requirements. The more detailed, system-based methods generally yield results that are more representative of facility requirements; however, they are also more data intensive.

The modeling method used in the tool is similar to that proposed by Leslie and Minkarah (1997) and Kaiser (1994). That is, system-based models, which are unique to each facility, are used to forecast renewal needs. The modeling decision was based on data available for application of the tool. Less data-intensive approaches, such as the formula-based methods mentioned above, might also be employed depending on the sophistication of the owner and the desired level of planning detail. The facility system models are based on the UNIFORMAT standard.[8] R. S. Means, a major provider of facility cost data, also uses this standard. The types of systems composing each facility

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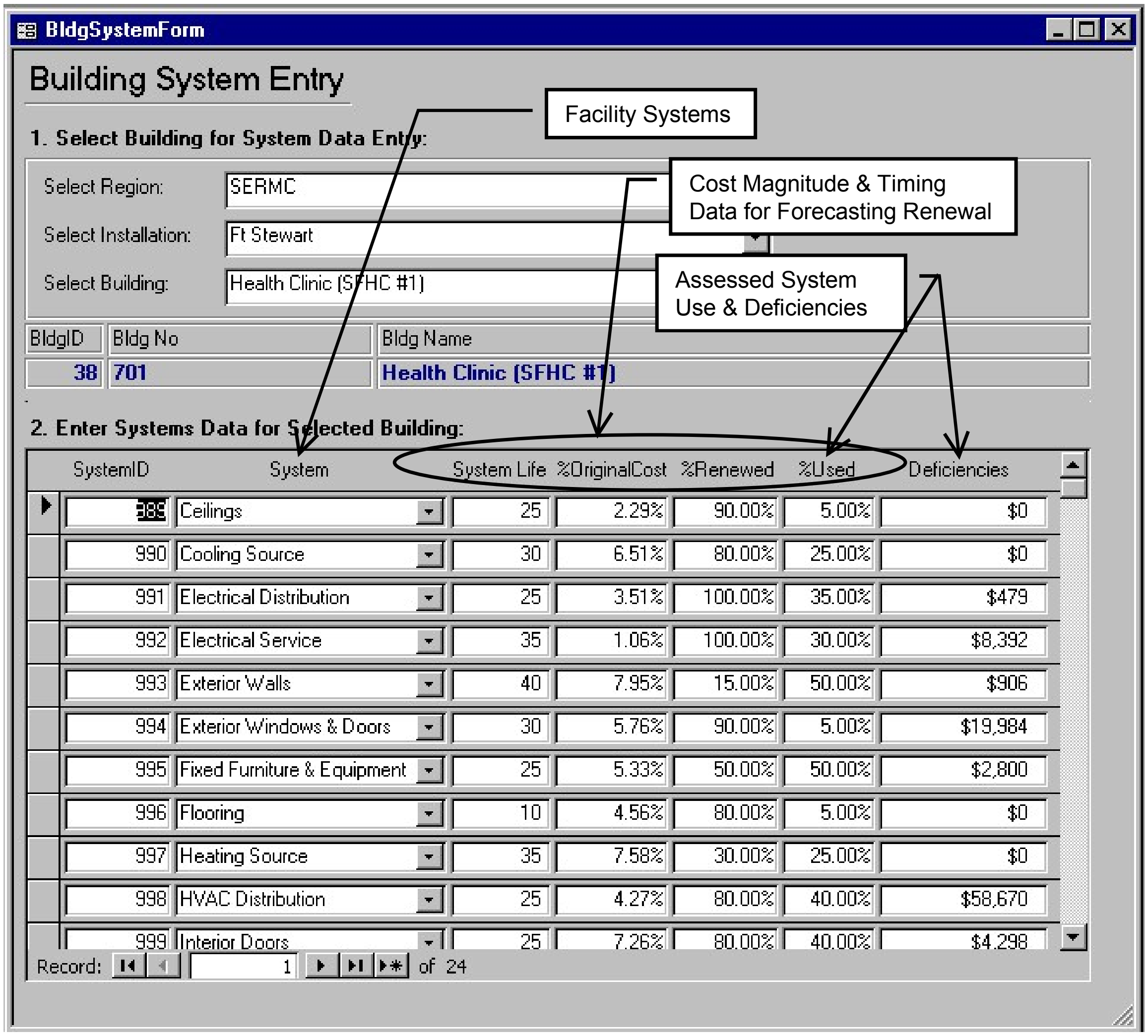
Exchange Report. Both reports provide detailed square foot costs for facility operations and maintenance based on extensive survey data.

[8] UNIFORMAT was developed by the General Services Administration (GSA) and American Institute of Architects (AIA) to provide a structure for organizing systems data; it is now recognized as an American Society of Testing and Measures (ASTM) standard (ASTM 1994). Other standards in use include the MASTERFORMAT developed by Construction Specifications Institute (CSI) and the F. W. Dodge Construction System Costs. The U.S. Army Construction Engineering Research Laboratory (CERL) has employed a unique hierarchy using twelve primary facility systems (Uzarski and Burley 1997).

model are based on R. S. Means' "major classifications" or UNIFORMAT's "level 3" categories. Facilities are thus modeled down to individual elements (e.g., exterior walls, partitions, elevators, or heat generation systems). The database component also allows these elements to be aggregated as group elements (e.g., superstructure, interior construction, or conveying systems).

Figure 3-6 shows a screen shot from the tool of a sample building with a portion of its component systems. The figure also highlights the types of data that characterize each system. The percentage used (*%Used*) and sum of deficiencies costs (*Deficiencies*) typically result from an engineering condition assessment or an ongoing preventive maintenance program. Each system is assigned an expected service life (*System Life*). Manufacturer's literature, Means (1998), and Boeckh's Building Valuation Manuals are



BldgSystemForm

Building System Entry

Facility Systems

Cost Magnitude & Timing Data for Forecasting Renewal

Assessed System Use & Deficiencies

1. Select Building for System Data Entry:

Select Region: SERMC

Select Installation: Ft Stewart

Select Building: Health Clinic (SFHC #1)

BldgID	Bldg No	Bldg Name
38	701	Health Clinic (SFHC #1)

2. Enter Systems Data for Selected Building:

SystemID	System	System Life	%OriginalCost	%Renewed	%Used	Deficiencies
989	Ceilings	25	2.29%	90.00%	5.00%	$0
990	Cooling Source	30	6.51%	80.00%	25.00%	$0
991	Electrical Distribution	25	3.51%	100.00%	35.00%	$479
992	Electrical Service	35	1.06%	100.00%	30.00%	$8,392
993	Exterior Walls	40	7.95%	15.00%	50.00%	$906
994	Exterior Windows & Doors	30	5.76%	90.00%	5.00%	$19,984
995	Fixed Furniture & Equipment	25	5.33%	50.00%	50.00%	$2,800
996	Flooring	10	4.56%	80.00%	5.00%	$0
997	Heating Source	35	7.58%	30.00%	25.00%	$0
998	HVAC Distribution	25	4.27%	80.00%	40.00%	$58,670
999	Interior Doors	25	7.26%	80.00%	40.00%	$4,298

Record: 1 of 24

Figure 3-6 Sample Facility Systems Model with Characteristic Data

among the sources that can supplement historical data and judgement in deriving estimates for system life. Systems are also ascribed a value representing their cost as a percentage of original construction cost (*%Original Cost*). The summed cost of each system comprising a facility equals the construction cost. These values may be derived from original construction documents or estimated using square foot cost data from R. S. Means or F. W. Dodge. Finally, each system is attributed a value representing the extent to which it is actually renewed (*%Renewed*). In other words, only a portion of some systems is replaced at the end of service life. Structural, mechanical, and exterior wall systems are examples of those with lower renewal percentages. For instance, renewal of exterior walls may only involve re-pointing masonry surfaces, rather than replacing masonry materials, such as brick or stone. Percent-renewed values may be estimated from Means (1998), historical records, or experience.

These system values are used to calculate and forecast cost-time profiles for renewal requirements. The remaining useful life and the renewal cost of each system is determined initially using the following equations:

Equation 3-1 Calculation of Remaining System Life

$$\text{Remaining Life} = \text{System Life} \times (1 - \%\text{Used})$$

Equation 3-2 Calculation of System Renewal Cost

$$\text{Renewal Cost} = \text{Current Replacement Value} \times \%\text{Original Cost} \times \%\text{Renewed}$$

where, *Current Replacement Value* = the current construction cost of a facility (see the calculation for this value in section 3.4)

A renewal cost-time profile is then generated for each building system as shown in Figure 3-7, where the time dimension is determined in seriatim by the following equation:

Equation 3-3 Calculation of System Renewal Time Profile

$$t_n = \text{Remaining Life} + \text{System Life} \times (n - 1), \quad \text{for n} = 1, 2, \ldots, \text{N and } t_n \leq 100 \text{ years}$$

The cost magnitude is modeled in constant terms; however, inflation is accounted for in the portfolio summary sheet, after all costs are aggregated. The renewal forecast model implicitly assumes that systems are replaced in-kind and that systems will be maintained over time in such a state so as not to compromise their expected service life.

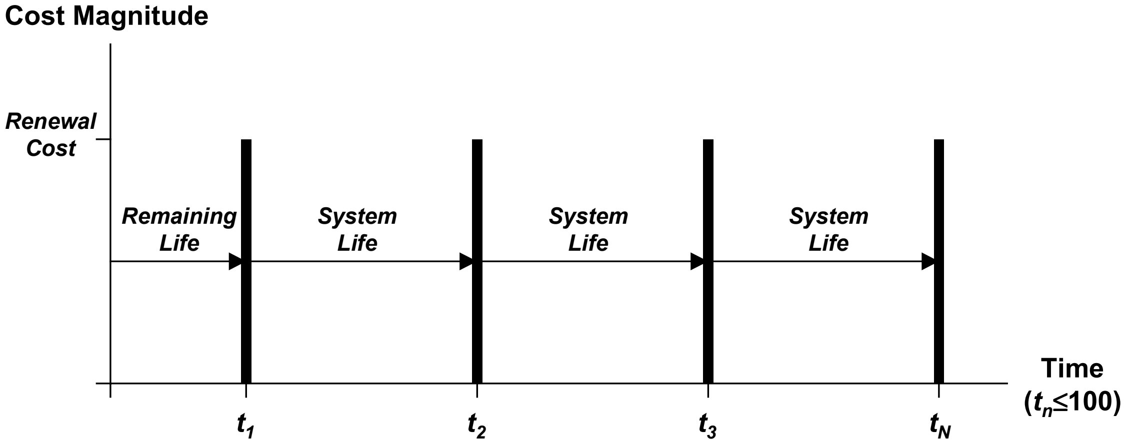


Figure 3-7 System Renewal Cost-Time Profile

From a technical perspective, it is generally recognized that facilities as a whole fail system by system. Accordingly, the research literature deals almost exclusively with deterioration at a system or component level.[9] However, the National Association of College and University Business Officers (NACUBO) proposed an aggregated methodology for forecasting system deterioration in financial terms (Rush 1991). The NACUBO model builds on assessed deficiencies (current backlog), replacement value, and estimated gross deterioration rates [see Ottoman et al. (1999) or Rush (1991) for a description of the model]. The model used herein is an adaptation of the NACUBO model. In keeping with the integrative framework, systems backlog is referred to as technical (or *sustainment*) backlog, and it is modeled in general form using the following equation:

Equation 3-4 Technical Backlog Deterioration Formula

$$\begin{aligned}\text{Technical Backlog}_n &= \text{Technical Backlog}_{(n-1)} \times (1 + \text{Rate}_{Det} + \text{Rate}_{Inf}) \\ &\quad + \text{Sustainment Rqmts}_n - \text{Sustainment Funding}_n\end{aligned}$$

where, *Technical Backlog* = Σ systems deficiencies costs;
n = year n;
Rate_{Det} = annual deterioration rate for aggregated backlog;

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[9] A review of any one of the four volumes published from the recent *Proceedings of the Eighth International Conference on Durability of Building Materials and Components*, Vancouver, Canada, 1999, NRC Research Press, is illustrative of the depth of ongoing research focused on modeling system level deterioration.

$Rate_{Inf}$ = annual inflation rate;
$Sustainment\ Rqmts_n$ = Σ maintenance and repair and renewal cost requirements in period n;
$Sustainment\ Funding_n$ = Σ maintenance and repair, renewal, and technical backlog funded in period n.

In effect, the equation is built on the notion that current systems backlog left unfunded will grow because of continued deterioration. That is, simple maintenance and minor repairs will turn into major repairs and eventually system failure and potentially other collateral effects. The equation assumes a constant, compounded rate of deterioration; however, this rate may vary from period to period. Moreover, the path of deterioration may assume a different form over time (Shohet et al. 1999), which not only affects the rate but also the assumption of compounding. The equation does present a simple approach for understanding the impact of various funding policies given current levels of system backlog. The degrees to which it has been used and verified is noticeably absent from the literature. However, Ottoman et al. (1999) suggest that formulas of its kind are in widespread use among practitioners, particularly among those offering maintenance planning services.

3.3.4 PROJECT COSTS FOR PLANNED FUNCTIONAL CORRECTIONS

Upgrades, alterations, and additions aimed at remedying functional and programmatic issues are generally the result of a detailed functional assessment. From a building perspective, such assessments are often part of a larger effort to develop a long-term plan for making adaptations and modifications to meet new and planned demands for building spaces and relationships. The output of concern for the modeling tool is the estimated costs and interdependencies of the *improvement* and *development* requirements, which represent projects or parts of projects. The database within the tool permits the phasing relationships for these requirements to be entered, so that the funding plan considers timing and interdependencies.

The sum of these identified requirements is viewed as the functional and capacity backlog of the facility. The underlying premise is that a detailed functional assessment effectively addresses the issues that are important to a particular organization and thus reflects a recognized level of current facility obsolescence. That is, facility projects that address changes in operations, business processes, services, missions, technology, and the like represent the current assessed level of facility obsolescence. This notion in concept mirrors that of technical backlog. Whereas the aggregate of deferred needs for correcting systems deterioration represents technical backlog, the aggregate of recognized needs for correcting facility obsolescence reflects functional and capacity backlog. The equations for modeling functional and capacity backlog are as follows:

Equation 3-5 Functional Backlog Formula

$$\mathit{Functional\ Backlog}_n = \mathit{Functional\ Backlog}_{(n-1)} \times (1 + \mathit{Rate}_{\mathit{Inf}}) + \mathit{Improvement\ Rqmts}_n - \mathit{Improvement\ Funding}_n$$

where, $\mathit{Functional\ Backlog}$ = Σ recognized upgrade and alteration requirements costs;
n = period n (in years);
$\mathit{Rate}_{\mathit{Inf}}$ = annual inflation rate;
$\mathit{Improvement\ Rqmts}_n$ = Σ upgrade and alteration requirements new to period n
$\mathit{Improvement\ Funding}_n$ = Σ upgrade and alteration funding in period n

Equation 3-6 Capacity Backlog Formula

$$\mathit{Capacity\ Backlog}_n = \mathit{Capacity\ Backlog}_{(n-1)} \times (1 + \mathit{Rate}_{\mathit{Inf}}) + \mathit{Development\ Rqmts}_n - \mathit{Development\ Funding}_n$$

where, $\mathit{Capacity\ Backlog}$ = Σ recognized addition requirements costs;
n = period n (in years);
$\mathit{Rate}_{\mathit{Inf}}$ = annual inflation rate;
$\mathit{Development\ Rqmts}_n$ = Σ addition requirements new to period n
$\mathit{Development\ Funding}_n$ = Σ addition funding in period n

The above equations treat known *improvement* and *development* requirements as backlog to be considered when formulating facility investment strategies. This backlog declines as requirements are funded and increases as new requirements are determined over time. The functional and capacity backlog equations are nearly identical to that used for calculating technical backlog, with the exception of the missing deterioration rate. Functional and capacity backlog are not modeled as growing entities per se. In contrast to physical system deterioration, *improvement* and *development* needs that are not funded do not cause an increase in the same needs in the future.

The underlying notion is that obsolescence measures the misfit of the facility to the intended activity and depends largely on human perceptions and decisions (Raftery

1991). The identification of functional requirements is therefore a matter of continual assessment, where the degree of fit is analyzed and resulting project remedies decided. The path of divergence from fit to misfit is, as Bon (1989) suggests, a dynamic one influenced by economic changes. Nonetheless, facilities are recognized for having finite functional lives (Ang and Wyatt 1999), and arbitrary depreciation formulas are applied as a measure. A rate of growth for obsolescence backlog could be approximated from the chosen depreciation method employed. However, the intent of this modeling effort is to integrate real requirements, those periodically recognized as solutions to perceived needs, with multi-period funding plans for reshaping the facility combination.

3.3.5 PROJECT COSTS FOR PLANNED NEW FACILITIES

New facilities consist of those replacing existing assets and those added to the portfolio to accommodate growth in services or new missions. Generally, these new facility requirements are seen as part of a larger capital *development* plan and program. Both replacement and new facilities are modeled in terms of their costs to plan, design, and build. In addition to these one-time capital costs, each new facility is modeled with associated *operations* and *sustainment* costs. Costs for new facilities are treated as planning estimates based on square foot quantities and rates. The modeling tool allows the user discretion in how new and replacement facilities are considered. Existing asset requirements may be considered in isolation, prior to adding the requirements for planned facilities. When replacement facilities are added, all requirements for the assets replaced are eliminated from the cash flow requirements. New and replacement facilities may be regarded as requirements at the outset, and thus added to functional and capacity backlog, or they may be treated as one-time requirements in the planned year of execution with matching funding.

3.4 Modeling Facility Condition Indicators: Techniques & Practice

The significance of the aforementioned backlog equations will now become apparent, as their combination with current replacement value in establishing benchmarks for monitoring the condition state of facilities is explained. As discussed in the previous chapter, a financial-based index is gaining wide use and acceptance in practice. The facility condition index is a dimensionless ratio of backlog costs over the current replacement value of the facility portfolio. The concept is extended in this research to account for the physical deterioration of facility systems, the functional obsolescence of facility spaces and relationships, and the capacity of existing facilities. The indicators for each are termed consistently with the notions of backlog described above and are modeled by the formulas below. To represent the holistic condition of facilities, an additional index is introduced. Called the comprehensive condition index, this ratio incorporates the sum of technical, functional, and capacity backlog.

Equation 3-7 Formulas for Facility Condition Indices

$$\textit{Technical Condition Index} = \textit{Technical Backlog} / \textit{Current Replacement Value}$$

$$\textit{Functional Condition Index} = \textit{Functional Backlog} / \textit{Current Replacement Value}$$

$$\textit{Capacity Condition Index} = \textit{Capacity Backlog} / \textit{Current Replacement Value}$$

$$\textit{Comprehensive Condition Index} = \textit{Total Backlog} / \textit{Current Replacement Value}$$

where, *Total Backlog* = Σ technical backlog, functional backlog, and capacity backlog

The current replacement value represents the estimated cost to construct each facility in the portfolio in-kind based on today's building costs. Also referred to as plant replacement value, this concept is widely used among public and institutional owners as a means for estimating the value of facilities [see for example Ottoman et al. (1999), Leslie and Minkarah (1997), or Sartori and Arnold (1997)]. Limited secondary markets for public and institutional facilities necessitate this valuation approach, as there is a general lack of comparable market price data. Moreover, the use of replacement value provides a more consistent measure for comparison with backlog. That is, the costs associated with eliminating backlog are more related to construction costs imputed in replacement value, rather than the market price associated with a facility. The equation used to estimate replacement value is consistent with the square foot cost formulas used by R. S. Means and F. W. Dodge and is as follows:

Equation 3-8 Calculation of Current Replacement Value

$$\textit{Current Replacement Value} = \textit{Facility Size} \times \textit{Base Construction Cost} \times \textit{Area Cost Factor} \times \textit{Adjustment Factor}$$

where, *Facility Size* = gross square feet;

Base Construction Cost = design and construction costs per square foot;
Area Cost Factor = cost adjustment based on facility location;
Adjustment Factor = cost adjustment for different owners to account for contingencies, secondary plant costs, installed equipment, design complexity, and administrative overhead.

3.5 Interrelationships between Facility Cash Flows

The interrelationships among cash flow requirements are prevalent. A number of interrelations are modeled within the tool; however, some remain for future work or require the user to manually adjust requirements. The primary intent of the tool is to model the interrelation of requirements, funding, backlog, and the resulting condition index. Requirements interrelationships that are currently modeled by the tool include: 1) the addition of unfunded maintenance and repair and renewal costs to technical backlog, 2) the addition of new *improvement* and *development* requirements to functional and capacity backlog, 3) the addition of utilities and maintenance and repair costs associated with new and replacement facilities to the portfolio requirements, and 4) the elimination of all requirements, including backlog, that are associated with replaced or disposed facilities. In addition, the database component of the tool permits project interdependencies to be taken into account, so that funding plans may consider practical constraints for executing *improvement* and *development* projects.

Interrelations, which are commonly recognized, yet not modeled include the impact of maintenance and repair on system renewal cycles, the effect of system renewal on technical backlog, and the influence of *improvement* projects on utilization, utilities, and maintenance and repair costs. The influence of maintenance on the expected service life of a system is well known throughout the literature [see for example Ottoman et al. (1999), NRC (1993), and NRC (1991)]. However, the task of modeling this interaction over a long period with several renewal cycles is a significant challenge, one that is reserved for future work. For now, the tool models the remaining useful life of the system and assumes equidistant renewal cycles thereafter based on the expected system life. In addition, while unfunded renewal is added to technical backlog, that which is funded does not make a corresponding debit to backlog. This is a practical limitation of the modeling method, as well as the level of decision-making considered. The portfolio summary sheet in the modeling tool aggregates all requirements by investment class, and funding allocation decisions are made at this level. Consequently, there is no direct modeling link from these macro allocations to the specific systems renewed at particular facilities. Modeling this effect necessitates mixing investment planning decisions with detailed execution decisions, which is not the intent of this tool.

Upgrades, alterations, and additions to facilities have an obvious impact on recurring costs. For example, system upgrades such as energy efficient lighting systems or windows, will undoubtedly lower the cost of utilities. Furthermore, facility alterations are likely to lower utilization costs, and facility additions will certainly increase utilities and maintenance and repair costs. The tool facilitates modeling these inter-effects, but it is left to the user to manually adjust costs on appropriate cash flow worksheets.

Chapter 4 Application Background & Data Collection

4.1 Introduction

This chapter provides background for the application of the framework and tool developed in the course of the research. The application environment is initially described. Two facility portfolios, which serve as the application "test-bed," are introduced, and the scopes of their assets are profiled. Data collection is addressed next with a description of the types and sources of data used in the application. The integrative framework provides a structure for assembling the facilities data. Finally, initial settings for the cash flow modeling variables are described.

The framework and tool are applied in an actual setting to demonstrate the practical feasibility of modeling and analyzing asset-based cash flow requirements, levels of capital commitment, and resulting facilities conditions. By means of empirical analysis, the interaction of capital investment decisions, anticipated facility condition, and policy-level objectives for sustaining and modernizing sample portfolios are explored. In this way, the analysis elucidates the tradeoffs between capital funding and facility condition. Although the application is carried out in a specific environment and facility context, the general features of the framework and tool are preserved. To this end, the application aims to demonstrate the generalizability of the framework and tool among different owner environments and classes of infrastructure assets.

4.2 The Application Environment

Healthcare facilities at select U.S. Army installations served as sample portfolios for application of the framework and tool. Choice of the application environment was largely motivated by the researcher's affiliation with the U.S. Army Medical Department (AMEDD). This selection had the dual benefit of facilitating the data collection process and demonstrating the practical use of the tool on a real data set.

4.2.1 THE ARMY HEALTHCARE DELIVERY SYSTEM

The AMEDD commands an extensive healthcare delivery system ranging from front-line medics and mobile hospitals on the battlefield to fixed peacetime facilities located at military installations throughout the world. Through this vast network of health services that includes contracted, civilian, and military care providers, the AMEDD seeks to preserve the health of military service members, their families, and military retirees.

The healthcare delivery network depicted in Figure 4-1 consists of a hierarchy of geographic and functional subsidiary organizations. This hierarchy provides a command and control structure that facilitates the transfer of health care services and supporting resources among subordinates. For example, the AMEDD can cross-level resources among the subordinate functional and regional commands, which in turn can apportion resources across installations within their borders.

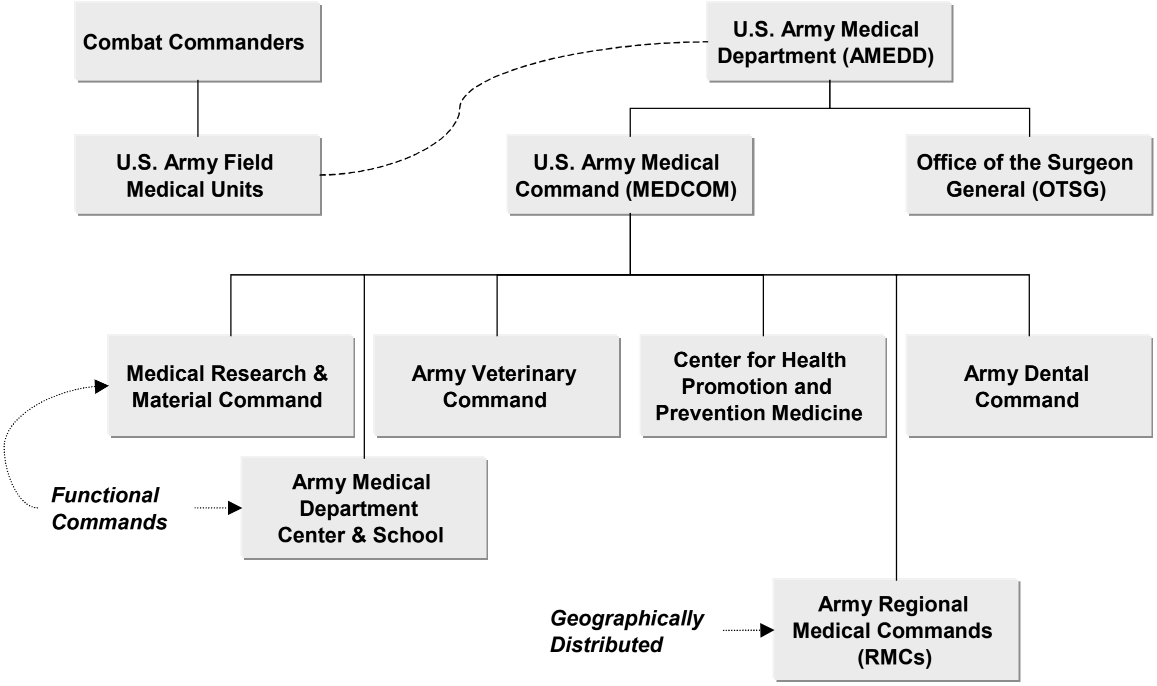


Figure 4-1 AMEDD Organization [Adapted from AMEDD (2001)]

Those organizations arrayed geographically are known as Regional Medical Commands (RMCs), and they are composed of a number of medical treatment and supporting facilities located at Army installations within their boundaries. Figure 4-2 shows the medical regions, which include four in the U.S., one covering Europe, and one spanning the Pacific Rim.

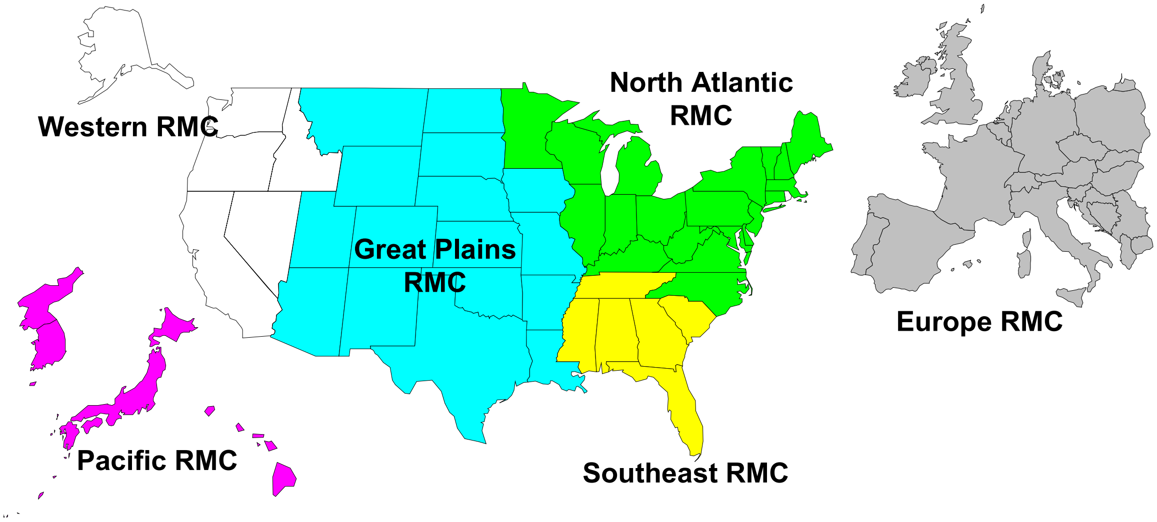


Figure 4-2 AMEDD Regional Medical Commands [Adapted from AMEDD (2001)]

The complementary functional commands provide specialized health related support and are in some cases distributed across many Army installations (e.g., the Veterinary Command has a treatment facility located at nearly every defense installation). In other cases, the functional commands are centralized at a single location (e.g., the Army Medical Center and School is situated at Fort Sam Houston, Texas).

4.2.2 THE ARMY HEALTHCARE INFRASTRUCTURE BASE

The overall infrastructure base supporting the AMEDD consists of over 1600 different facilities accounting for some 35 million square feet and $8 billion in replacement value (HFPA 1998). Annual investments for sustaining and modernizing this facility portfolio generally exceed $330 million (HFPA 1999). With nearly $500 million of construction in progress in 2000, the Army ranked comparably to the largest private healthcare owners. In 2000, HCA-Healthcare Co. reported $442 million of construction in progress followed by Tenet Healthcare Corp. with $424 million (Korman 2000).

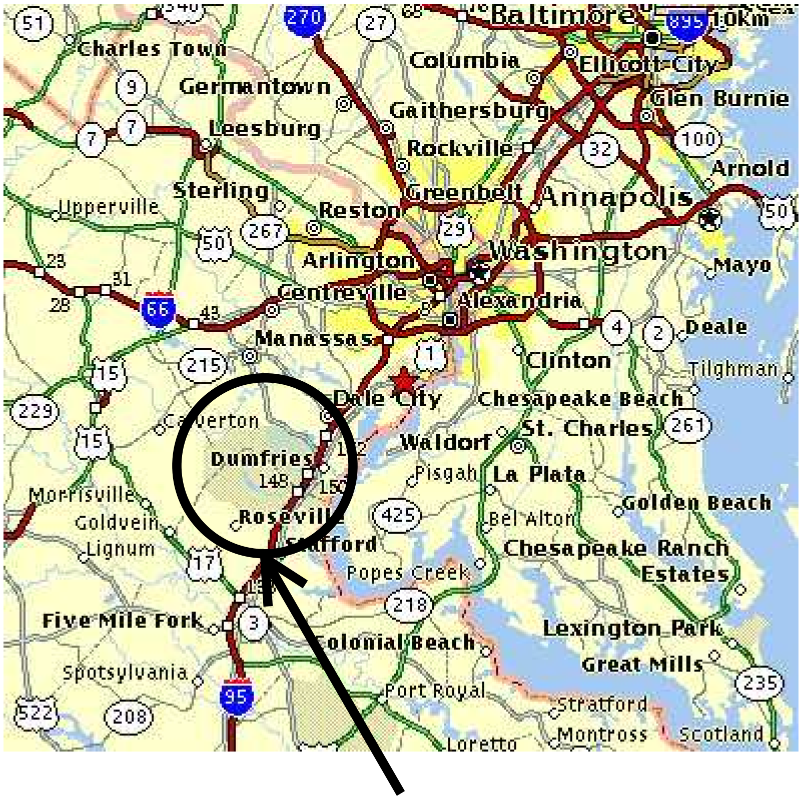
The types of facilities in the Army portfolio vary from large-scale medical centers with specialized medical treatment and teaching capabilities, to standard hospitals, to health and dental clinics that provide primary care services. Other healthcare related facilities include medical research laboratories, medical supply warehouses, veterinary care facilities, medical education and training facilities, medical administration facilities, ancillary pharmacies, and central energy plants. A typical installation has a hospital or medical center with three to five outlying health and dental clinics and various other medical support buildings. Installations with lesser populations may have only one clinic that combines health and dental services.

4.2.3 THE APPLICATION PORTFOLIOS

Healthcare facilities at two Army installations, Fort Belvoir and Fort Stewart, were selected for application of the framework and tool. These installations were chosen as representative samples of infrastructure supporting the Army. Fort Belvoir is a "sustaining" post that serves a range of logistical and administrative organizations, including two Army major command headquarters and a number of defense staff agencies. Fort Stewart is a "mission" post that supports an active, readily deployable Army division. These installations were also chosen because they both are alike in scope of healthcare facilities. Each is similar in terms of hospital size, number of outlying support facilities, total capacity, and overall replacement value. However, each is different in terms of facility age and current condition. The similarity in scope with contrasting facility condition provides a relative basis of comparison among the investment strategies investigated in the analysis that follows. The following two sections describe the two installations and profile their infrastructure scope further.

4.2.3.1 PORTFOLIO I: FORT BELVOIR, VIRGINIA

Shown in Figure 4-3, Fort Belvoir is located in the national capital area roughly 17 miles southwest of Washington D.C. Comprising over 8,600 acres, this post is home to a number of federal government organizations, mostly military. In addition to hosting these primarily administrative tenants, Fort Belvoir provides several support activities, including base housing, commissary and post exchange operations, child care and schooling, and healthcare, for military members stationed in the Metropolitan District of Washington D.C.



Fort Belvoir

Figure 4-3 Regional Map with Fort Belvoir

The core healthcare facility at Fort Belvoir is DeWitt Army Community Hospital, which is part of the North Atlantic Regional Medical Command (NARMC). Three health clinics, one dental clinic, one medical warehouse, two medical administration buildings, a pharmacy annex, and two veterinary clinics also comprise the health system, which serves over 125,000 beneficiaries and accounts for nearly 620,000 annual visits (HFPA 2000). The extent of the infrastructure base is presented in Table 4-1. Table 4-2 summarizes facilities by use.

Total Number of Facilities:		11	
Total Current Replacement Value:		$100,053,803	
Total Gross Square Feet:		409,264	
Estimate of Technical Backlog:	$22,871,621	Technical Condition Index:	0.23
Estimate of Functional Backlog:	$15,106,506	Functional Condition Index:	0.15
Estimate of Capacity Backlog:	$715,836	Capacity Condition Index:	0.01
Estimate of Total Backlog:	$38,693,963	Comprehensive Condition Index:	0.39
Avg. Facility Age (Years)	40.0	Avg. Facility Age per GSF (Years)	44.8

Table 4-1 Fort Belvoir Healthcare Facilities Profile

Facility Type	No. of Facilities	Gross Square Feet	Current Replacement Value	Avg. Age (Years)	Estimate of Total Backlog	Comprehensive Condition Index
Administration	2	6,041	$1,057,142	52.0	$352,798	0.33
Dental Clinic	1	13,272	$3,436,586	30.0	$511,505	0.15
Hospital	1	260,245	$77,013,199	43.0	$33,593,101	0.44
Laboratory	1	800	$202,595	1.0	$4,554	0.02
Medical Clinic	3	35,776	$7,533,086	48.0	$2,099,616	0.28
Medical Warehouse	1	78,282	$7,684,762	55.0	$2,132,388	0.28
Veterinary Clinic	2	14,848	$3,126,433	31.5	N/A	N/A

Table 4-2 Fort Belvoir Healthcare Facilities Profile by Use

The profiles in Tables 4-1 and 4-2 represent the current condition of healthcare infrastructure at Fort Belvoir and serve as the baseline for developing facility investment strategies. The estimated total backlog is 39% of the current replacement value of this aging facility base. It is evident from the technical condition index that facility systems have deteriorated to undesirable levels, as estimated systems backlog is 23% of current replacement value. While the capacity condition index indicates a marginal need for additional facility space, it is apparent from the functional condition index that facility space has obsolesced and that serviceability has been compromised. From Table 4-2, it is clear that the hospital dominates the portfolio, accounting for 77% of the total replacement value and 64% of the size (gross square feet). Correspondingly, the hospital accounts for the bulk of total backlog. With the exception of the extremely small laboratory, healthcare facilities at Fort Belvoir are well past 30 years of use and are in generally poor condition.

4.2.3.2 *Portfolio II: Fort Stewart, Georgia*

Fort Stewart is located on the eastern border of Georgia some 35 miles southwest of Savannah (see Figure 4-4). Occupying nearly 280,000 acres, this post is the largest installation east of the Mississippi River. The 3rd Infantry Division (Mechanized) is the predominant unit stationed at Fort Stewart, which also provides the training grounds for over 50,000 reserve soldiers per year. The post supports training ranges for tanks, field artillery, helicopter gunnery, and small arms. Hunter Army Airfield, located just west of Savannah, is a satellite of the Fort Stewart range. The airfield supports helicopter operations for both the Coast Guard and Army.

Fort Stewart

Figure 4-4 Regional Map with Fort Stewart

Healthcare facilities at Fort Stewart fall within the Southeast Regional Medical Command (SERMC). Winn Army Community Hospital is the primary facility for the delivery of specialized healthcare, and it is augmented by four outlying health clinics and three dental clinics, including one health clinic and one dental clinic at Hunter Army Airfield. A mental health clinic, medical warehouse, three veterinary clinics, medical administration building, and central energy plant also support the healthcare delivery system, which serves some 65,000 beneficiaries and accounts for nearly 400,000 annual visits (HFPA 2001). Table 4-3 summarizes the basic facilities profile, and Table 4-4 outlines facilities scope and condition by use.

Total Number of Facilities:		15	
Total Current Replacement Value:		$112,485,056	
Total Gross Square Feet:		480,254	
Estimate of Technical Backlog:	$12,905,117	Technical Condition Index:	0.11
Estimate of Functional Backlog:	$10,527,522	Functional Condition Index:	0.09
Estimate of Capacity Backlog:	$578,289	Capacity Condition Index:	0.01
Estimate of Total Backlog:	$24,010,928	Comprehensive Condition Index:	0.21
Avg. Facility Age (Years)	21.9	Avg. Facility Age per GSF (Years)	15.6

Table 4-3 Fort Stewart Healthcare Facilities Profile

Facility Type	No. of Facilities	Gross Square Feet	Current Replacement Value	Avg. Age (Years)	Estimate of Total Backlog	Comprehensive Condition Index
Administration	1	3,750	$567,365	7.0	$23,065	0.04
Central Energy	1	8,100	$1,494,523	17.0	$212,583	0.14
Dental Clinic	3	35,436	$7,933,090	35,7	$1,898,662	0.24
Hospital	1	332,549	$85,083,486	17.0	$20,295,318	0.24
Medical Clinic	5	81,330	$14,806,035	14.6	$687,975	0.05
Medical Warehouse	1	9,000	$763,867	18.0	$237,342	0.31
Veterinary Clinic	3	10,089	$1,836,690	30.0	$655,983	0.36

Table 4-4 Fort Stewart Healthcare Facilities Profile by Use

Baseline conditions at Fort Stewart are much better relative to Fort Belvoir, and the younger facility base requires proportionally less investment in improving facility systems and spaces. Both the technical condition index and functional condition index in Table 4-3 indicate that the facility portfolio has undergone moderate deterioration and obsolescence. From a capacity standpoint, existing facilities seem to accommodate current and projected levels of demand. Again, the hospital accounts for the majority of portfolio value (75%), size (69%), and total backlog (85%). The veterinary clinics and medical warehouse appear in the worst condition, followed by the hospital and dental clinics. However, overall the healthcare portfolio at Fort Stewart appears in moderate condition.

4.3 Data Collection

The integrative framework provided the organizing construct for collecting data representative of facility investment requirements. The primary data consisted of facility costs, which were broadly sorted into *operations*, *sustainment*, *improvement*, and *development* categories, and facility inventory with general descriptive information. Historical facility cost reports, master plan documents, capital programs, and an internet-based database containing facility condition data were used in assembling common data sets for the two application portfolios. Figure 4-5 illustrates how the primary data elements were organized within the framework.

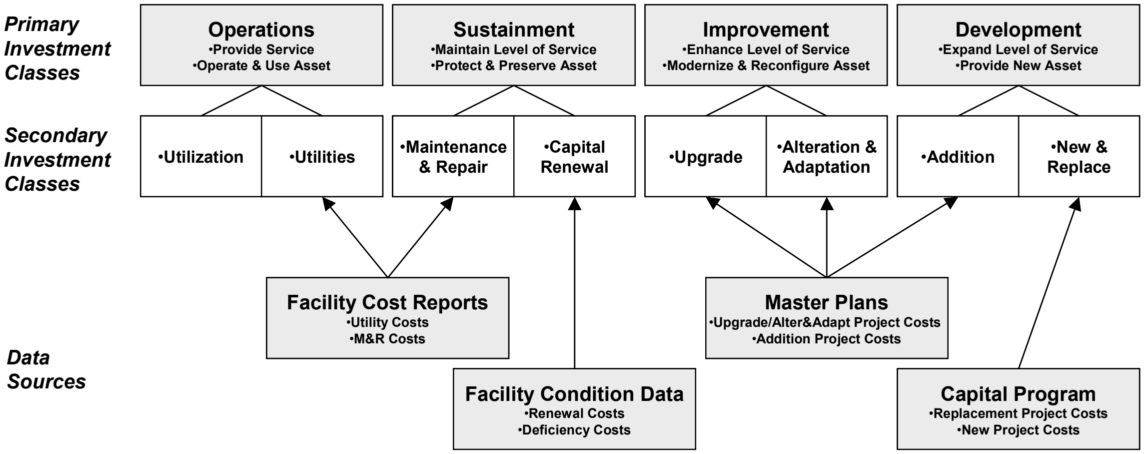


Figure 4-5 Data Collection Based on Integrative Framework

The primary data originated from two Army Medical Department organizations: the Assistant Chief of Staff for Installations, Environment, and Facility Management (IEFM) and the Health Facility Planning Agency (HFPA). Both groups work jointly in formulating policy and executing life-cycle activities (i.e., operations, maintenance, development, budgeting, acquisition, and disposition) associated with Army healthcare facilities.

4.3.1 FACILITY COST REPORTS

Cost reports known as Repair, Alterations, Maintenance and Operations Plans (RAMOPs) were obtained for each installation from 1997 to 2000 with budget projections for 2001. These reports are generated annually by health facility managers at the installation level and are maintained at IEFM. The RAMOPs contain detailed utility costs, maintenance and repair costs, and inventory data; however, the data is aggregated by installation. Deriving facility-based cost data is a systemic problem, as many buildings are not yet individually metered to measure utility consumption. In addition, the use of installation-wide maintenance contracts confounds the representation of facility-based costs, as indirect costs are difficult to allocate.

A simple analytic technique was employed to desegregate cost data per building. A use factor was assigned to each facility based on its type. For example, hospitals and laboratories are high-use facilities with intensive equipment demands, whereas administration buildings and warehouses generally operate daily during set hours with much less equipment demand. Accordingly, hospitals and laboratories were assigned a higher use factor and were apportioned a greater cost burden from the aggregate. The use factors were validated in part by comparing desegregated maintenance costs per building with budgeted costs. IEFM budgets maintenance costs using a formula method that also assigns unit values based on facility type. IEFM uses higher square-foot costs for facilities such as hospitals, laboratories, and clinics. In general, the derived use factors yielded historical costs per building that were similar to amounts that would have been budgeted using IEFM formulas.

The facility cost reports provided input for the utility portion of *operations* costs and the maintenance and repair portion of *sustainment* costs. Although these costs are represented simply as utility and maintenance and repair during the analysis, the RAMOPs contain information that is more detailed with specific types of costs. These details were preserved when entered into the database supporting the tool, so that a more detailed analysis of cost types could be conducted after allocation strategies are considered. For example, utility costs can be divided into electric, water, sewer, natural gas, fuel oil, and steam. In addition, maintenance and repair costs can be considered in terms of support personnel, installation-wide contracts, unique service contracts, testing and certification contracts, and engineering and administration support. These organizationally unique cost elements might eventually be used in modeling such effects as an energy upgrade project that decreases power consumption.

4.3.2 FACILITY CONDITION DATA

Building system and condition data were obtained from a web-based production site maintained by an HFPA contracted engineering firm. The web site permitted quick and orderly access to the results of engineering assessment data for each healthcare facility at a given installation. The parts of the assessment data relevant to this research included: 1) a detailed tabulation of current facility deficiencies with estimated repair costs, 2) a building system model with the average life span, the percentage of total construction cost, and the percentage of renewal for each system, and 3) a building condition model with the estimated percentage of remaining useful life for each system.

The web-based system contained a number of pre-defined reports for viewing deficiencies by priority, system, and category. For this research, deficiencies were sorted by system and repair costs totaled accordingly. However, the more specific information can effectively assist planners in prioritizing and packaging projects during the execution of a chosen allocation strategy. Deficiency costs and system data provided the technical input for the analytic tool. Deficiency costs represented technical backlog, while building system data provided the necessary parameters for calculating renewal cost projections. This data effectively populated the remainder of the *sustainment* portion of the facility investment framework.

4.3.3 MASTER PLAN DOCUMENTS

Functional project data was extracted from master plan documents developed by teams of government and contracted architects, clinicians, and planners. The master plan provides a guide for improving existing health facilities and developing new facilities. The master plan systematically reviews facility utilization and projected healthcare workload to estimate space requirements and compares these requirements with current facility layouts. Organizational objectives, planned changes to healthcare delivery, employment of new medical technologies, assessment of functional and aesthetic conditions, and other factors are also incorporated as multiple options for altering, upgrading, replacing and adding to existing spaces are evaluated. The culmination of this effort is a logically phased plan for adapting and modernizing healthcare facilities with accompanying cost estimates. These estimates effectively represent the remediation of facility obsolescence.

Master plan documents are available at HFPA and are generally considered valid for a five to ten year timeframe. The resulting estimates are presented as a number of interdependent cost requirements that can be packaged in a variety of ways for execution. Thus, depending on the pace of execution and impending budget constraints, projects can be modeled in consideration of how and when each must be accomplished. For example, development of a Woman's Health Center on one floor of a hospital may depend on the displacement of a current function prior to commencement. Modeling these interdependencies provides a fairer representation of functional requirements over time. Requirements from the master plan provided input to the *improvement* section and part of *development* section of the facility investment framework.

4.3.4 CAPITAL PROGRAMS

Capital programs are developed and submitted annually for input into the defense budgeting system. These programs generally look forward to the next budget year plus four to five years beyond and serve as a guide for future *development* requirements. Known as the Future Years Defense Plan (FYDP), the capital program for Army health facilities is maintained by HFPA. The FYDP for federal fiscal years 2001 to 2006 was used to furnish the remaining requirements for the *development* section of the facility investment framework.

Each project in the FYDP is supported by detailed information in a Department of Defense Form 1391 (DD-1391). This form consists of several pages that include information such as project scope and estimated costs, economic analysis of project alternatives, environmental assessment, disposition plan for related buildings, supporting facility requirements, and other information relevant for project evaluation. When submitted to Congress, the FYDP is supplemented by DD-1391s for projects one or two years from execution. Project costs, scope, and disposition plans for related facilities were used in this research for modeling planned *development*.

4.3.5 SECONDARY DATA

Secondary data sources included Army Regulations, Army Instructional Pamphlets, Office of Management and Budget Circulars and miscellaneous government publications. Secondary data sources were relied upon mainly for descriptive data (e.g., installations, locations, zip codes, facility addresses) and cash flow modeling variables (e.g., discount rates, inflation rates, and valuation cost factors). The specific documents used are cited with corresponding topics throughout the thesis.

4.3.6 DATA RELIABILITY, VALIDITY, LIMITATIONS

Beyond basic inventory data, the majority of the data collected was financial in nature and ranged from historical costs for *operating* and *sustaining* facilities to estimated costs of system deficiencies, *improvements*, and *development*. Inventory data was easily validated by comparing that which was reported by local facility managers in the RAMOPs with that documented in the master plans and condition assessments. Minimal discrepancies between inventory reports were observed, and those that did occur were due mainly to the inclusion of non-health facilities used for administration or housing. *Operations* and *sustainment* of these facilities are generally not funded by the AMEDD. Consequently, although reported by local facility managers in some instances, the absence of these non-health facilities does not affect the reported costs used in this research.

The historical costs for utilities and maintenance and repair were tested for reliability in two ways. First, the annual costs from 1997 to projections for 2001 were compared across time for major fluctuations. Growth and decline were observed from year to year with and the data appeared relatively consistent. The percentage of average deviation from the sample mean was 5.5% for maintenance and repair and 7% for utilities at Fort Stewart. At Fort Belvoir, the percentage was 13% for maintenance and repair and 5% for utilities. The second test of reliability involved comparing costs on a unit (square foot) basis. Unit costs were reviewed by facility type across installations for a given year. The two application installations were supplemented with data from four additional installations.[10] The percentage of average deviation from the sample mean was no greater than 12.5% for utility costs across all facility types. Maintenance and repair data varied between 21% to 25% for several facility types, and the percentage for administration facilities was 31.5%. While maintenance and repair data varied to a greater extent than utility data, the values for both were deemed to fall within a reasonable range of one another. Historical costs were therefore judged reliable. The degree to which historical cost data represents valid utilities and maintenance and repair requirements is arguable. However, it was assumed that each installation fully funds utility requirements. It was also assumed that the level of historical maintenance and repair expenditure adequately represents ongoing requirements for sustaining facilities in a chosen state of quality.

An experienced engineering firm specializing in building assessments generated facility condition data. The methodology employed by this firm was uniformly applied to the installations under study. That is, multi-disciplined teams methodically assessed building systems using consistent means and methods. The data was subsequently reported so that any building from a given installation could be accessed to obtain the current state of systems with itemized lists of deficiencies. Repair costs for these deficiencies were based on standard R.S. Means cost data. These costs were adjusted by standard Army cost factors to account for the soft costs generally associated with military works.[11] The standardized, cost-based approach and the experience of the engineering firm were considered to yield reliable condition data. Relying on outside, objective

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[10] Utility and maintenance and repair data was also collected for Fort Benning, Georgia; Fort Rucker, Alabama; Fort Carson, Colorado; and Fort Leonard Wood, Missouri. The validation of data points was not statistically robust; however, the intent was to make a simple comparison across a small sample of installations to provide some benchmark for the unit costs.

[11] Cost factors were developed for *sustainment*, *improvement*, and *development* projects based on guidance from Army (1994). The *sustainment* cost factor equaled 1.2 and was derived by multiplying the following items: 1.1 for contingency, 1.057 for supervision and administration, and 1.03 for design. The *improvement* cost factor equaled 1.48 and was derived by multiplying the following items: 1.1 for contingency, 1.057 for supervision and administration, 1.2 for transition and equipment, and 1.06 for design. The *development* cost factor equaled 1.48 and was derived by multiplying the following items: 1.05 for contingency, 1.057 for supervision and administration, 1.2 for support facilities, 1.05 for equipment, and 1.06 for design. For each project or requirement, the "hard" cost for construction was multiplied by the appropriate cost factor to account for "soft" costs.

assessments avoided problems associated with subjective, non-standard approaches and internal tendencies to inflate backlog costs.[12]

Improvement and *development* projects resulting from master plans and capital programs were also judged reliable and valid. These requirements are developed through a series of on-site meetings facilitated by contracted architectural/engineering (A/E) firms. The A/E firms, HFPA representatives, and local executive and operational staff collaboratively assess existing functional conditions and organizational goals and develop plans for improving the physical environment. The methodology is employed consistently across all installations and is ultimately based on current and expected beneficiary populations. In other words, the requirements are driven by how well the facility presently supports healthcare delivery and how well it may serve in the anticipated future. Project costs are generally "order of magnitude" estimates of hard costs. The estimates were adjusted in the analysis to account for soft costs.

4.4 Initial Settings of Cash Flow Variables

Several variables necessary for modeling cash flows must be initialized prior to generating and analyzing the investment scenarios. These variables include: 1) inflation rates for *operations*, *sustainment*, and *development* (*improvement* is treated as new construction and is the same as *development*); 2) the overall system deterioration rate; 3) the building replacement threshold; 4) the real (or constant) discount rate; 5) the year of study; and 6) the types of cash flow models representing *operations* and *sustainment* requirements. The range of relevant values for each of these variables and the initial value assigned to each is described in the following sections.

4.4.1 INFLATION

In the analysis that follows, all cash flows and the discount rate are treated in real (or constant) terms. That is, inflation is set to zero. Modeling inflation-free cash flows is the "preferred method" for dealing with inflation in life cycle cost studies, as the problem

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[12] At the behest of Congress, the General Accounting Office (GAO) has generated a number of reports, including GAO (2000) and GAO (1998), that describe the difficulties federal agencies have encountered in developing methods for assessing and reporting deferred maintenance requirements. Among the cited issues was the use of different rating systems and their inconsistent application. Also cited, was the lack of third-party audits and the potential over- or under-estimation of reported backlog.

of aggregated costs with elements that inflate at different rates is avoided (Flanagan et al. 1989). Although the modeling tool permits different *operations*, *sustainment*, and *development* inflation rates, consideration of inflation is negligible when cash flows are adjusted to equivalent terms (i.e., discounted). Basic finance theory validates this claim. As long as inflation is treated consistently (i.e., nominal cash flows are discounted at nominal rates and real cash flows are discounted at real rates), the discounted results are the same (Brealey and Myers 1996). Equation 4-1 demonstrates this equality.

Equation 4-1 Equality of Discounted Nominal and Real Cash Flows

$$C_0 + \frac{C_1(1+i)}{(1+r)(1+i)} + \cdots + \frac{C_N(1+i)^N}{(1+r)^N(1+i)^N} = C_0 + \frac{C_1}{(1+r)} + \cdots + \frac{C_N}{(1+r)^N}$$

The left-hand side of the equation represents discounted nominal (or current) cash flows that include an inflation term $(1+i)$ up to period N. Since the discount rate must be treated consistently, the real rate (r) in the denominator appears with the inflation term also. The inflation terms thus cancel resulting in the discounted real (or constant) cash flows on the right-hand side of the equation.

4.4.2 SYSTEM DETERIORATION RATE

The system deterioration rate is set initially at 2% per annum. This rate effectively represents the real growth of backlog for facility systems and components in aggregate. The system deterioration rate models the future collateral effects of deferring the maintenance, repair, or renewal of a system. For example, failure to repair the building enclosure where water penetration is present may result in damage to interior systems and further damage to the enclosure. Although the rate is assumed constant in this analysis, it may vary from year to year. Shohet et al. (1999) describe deterioration paths for building components as varying in four typical patterns – concave, convex, linear, and s-shaped – over time. The specific value used for this rate is an assumption and is, consequently, a candidate for sensitivity testing. Rush (1991) estimates the range of reasonable values from 2% to 10%. While the initial value is conservative relative to this range, it is consistent with the value recognized by the practitioners responsible for the engineering assessment data used in this research.

4.4.3 REPLACEMENT THRESHOLD

The replacement threshold is initialized at 75%. This variable is used in determining replacement cycles. The period in which the ratio of total backlog to current replacement value (CRV) exceeds the replacement threshold represents the estimated year of replacement of the building or portfolio being considered. While perhaps conceptually unrealistic for a collection of facilities, the replacement cycle nonetheless represents a decisive point. That is, further recapitalization of existing assets is no longer desired for economic or other reasons. The replacement threshold is variable to account for the range of values that may be acceptable to a given organization. For instance, at the federal level, the U.S. Army's Assistant Chief of Staff for Installation Management (ACSIM) establishes management control points for the recapitalization of Army facilities. Repair and alteration projects that exceed 50% of the replacement value of a building require approval by ACSIM, rather than subordinate organizational levels (Army 1997). The threshold of 75% is chosen simply as a reasonable value for the replacement decision point.

4.4.4 DISCOUNT RATE

Since the framework and tool are applied to a federal agency, the discount rate is established based on guidance from the Office of Management and Budget (OMB).[13] OMB Circular No. A-94, which provides guidelines and discount rates for analyzing federal programs, recommends a real discount rate of 3.2% per annum for economic analyses spanning 30 years or more (Daniels 2001). A real rate is used for conformance with the inflation assumptions discussed above.

The selected rate equals the 30-year real interest rate on U.S. Treasury Bonds, thus matching the economic assumptions used in preparation of the President's budget. Choosing an appropriate discount rate for economic evaluations is a fundamental problem addressed in finance theory. Brealey and Myers (1996) provides depth on this

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[13] The Office of Management and Budget (OMB) is the arm of the Executive Office of the President that administers the preparation of the federal budget. In this capacity, OMB evaluates federal programs and policies and establishes funding priorities. OMB also oversees procurement, financial management, information, and regulatory policies. OMB publishes instructions and guidelines for the financial management of federal agencies by means of numbered circulars (OMB 2000).

topic from a corporate perspective, while Brueggeman and Fisher (1997) and Finnerty (1996) address discount rates from a real estate and project viewpoint, respectively. Also called minimum attractive rate of return (MARR) and opportunity cost of capital, the discount rate is typically an elusive number that imputes economic notions of risk and forgone opportunities. Discount rates typically exceed 10% per annum (in nominal terms) for the private sector; however, choosing public-sector discount rates is more controversial (De Neufville 1990). Many economists argue that public discount rates should parallel that of business and industry, while others promote lower rates equal to the interest on government-issued debt. De Neufville (1990) presents the reasoning for both arguments, concluding that public rates ought to approximate private rates. One undisputed point is that economic evaluations should analyze the sensitivity of results to the discount rate.

4.4.5 YEAR OF STUDY

The year of study for the analysis is 2000. The year of study is also the decision year for establishing a facility investment strategy. The bulk of the data collected for this research represents the state of facility conditions in 2000, and this year was consequently fixed for analytic consistency. The year of study can be changed to later years as actual condition data is updated.

4.4.6 TYPES OF CASH FLOW REQUIREMENTS

The following analysis models utility and maintenance and repair requirements based on projections from historical costs. Maintenance and repair cash flows may also be modeled using common budgeting formulas, such as unit cost per square foot or percentage of facility replacement value. Capital renewal requirements are modeled using the equation described in the previous chapter. That is, annual renewal requirements are forecasted for each facility system based on condition and expected useful life. The amplitude of renewal cash flows varies irregularly from period to period. Options are available for leveling these “lumpy” renewal requirements as a uniform series based on a simple average or an equivalent annual cost or as a gradient series based on a linear trend. *Improvement* and *development* requirements are based on facility master plans and current capital programs.

4.5 Summary

The framework and tool are applied to two facility portfolios within the U.S. Army Medical Department's infrastructure base. The two portfolios, located at Fort Belvoir, Virginia, and Fort Stewart, Georgia, are similar in size and scope, however they are much different in terms of facilities condition. These characteristics provide a comparative basis for analyzing investment scenarios defined in the following chapter. Data was collected and assembled for these two portfolios using the integrative framework as the organizing construct. Facility cost reports provided operational and maintenance and repair data. Data from engineering-based condition assessments was used in developing systems-level facility cost models and in summarizing current levels of technical backlog. Data from architectural assessments provided requirements for upgrades, alterations, and additions to existing facilities. Capital programming data was used in identifying new and replacement facilities. This data was entered into the modeling tool and cash flow variables were initialized prior to generating investment scenarios. The modeling tool permits cash flows to be manipulated using several variables, including inflation rates for different cash flow types, an overall system deterioration rate, the discount rate for determining equivalent cash flows, the year of study, and different means of modeling facility requirements. Investment scenarios are defined and analyzed in the next chapter.

Chapter 5 Application Results & Analysis

5.1 Introduction

This chapter presents the results and analysis of a range of "what-if" scenarios representing possible solutions for balancing facility investment and condition. Scenarios are framed in a budget context, which is discussed generally from the vantage of public and institutional owners. The budget context provides a real setting that is indicative of the capital constraints facing facilities decision-makers, and it serves as a basis for formulating investment scenarios. These scenarios are defined and analyzed in four investigation sections. The first considers boundary scenarios, which minimize and maximize facility condition over time. The second explores the minimum condition boundary in more detail by varying funding within a range of minimal levels. The third investigates a number of scenarios that lie between the boundaries. Funding is treated in a discretionary sense, as facilities condition is improved to various levels at different execution rates. The fourth considers scenarios that alter the mix of existing assets by adding or replacing facilities. The array of scenarios are then combined and analyzed as a collection of potential solutions using basic principles of engineering economics. Finally, the sensitivity of results to initial cash flow variables is analyzed. In each section, the results of the two portfolios (i.e., Fort Belvoir and Fort Stewart) are presented and analyzed concurrently so that differences and similarities can be observed for various strategies.

5.2 Developing and Analyzing Facility Investment Scenarios

5.2.1 DEVELOPING SCENARIOS IN A BUDGET CONTEXT

Facilities decision-makers generally consider alternative investment strategies in a budgetary context, where facility needs often exceed available funds, yet commitment to a minimum level of funding is critical to managing future liabilities. The budget context[14] depicted in Figure 5-1 recognizes the fiscal reality of many public and institutional owners who typically set minimum funding levels for maintaining assets in-place, while contemplating discretionary spending levels for recapitalization and acquisitions. In this setting, certain facility requirements are deemed essential, while other needs are subjected to further scrutiny and may ultimately be deferred to later periods. The core facility budgeting problem is thus twofold: 1) how to determine minimum funding levels to maintain a baseline facility condition and 2) how to allocate discretionary funding to enhance current facility condition.

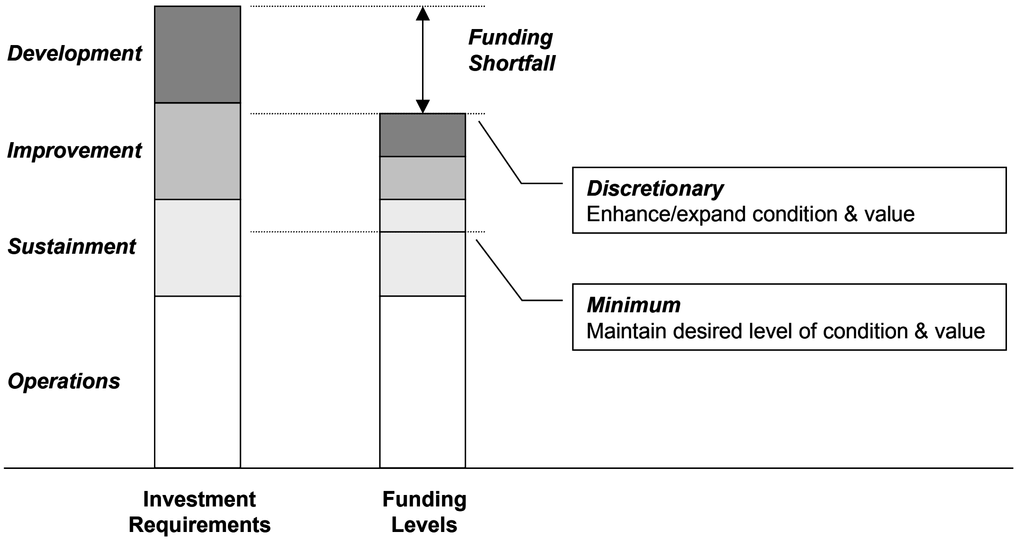

Figure 5-1 Budget Context in Terms of Integrative Framework

In the analysis that follows, scenarios are developed in view of these two central budgeting questions. When budgets are constrained, facilities decision-makers are

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[14] Grigg (1988) and Lemer and Wright (1997) review this general budget context for managing public infrastructure, and Gardiner (1991) describes the same from an institutional perspective.

generally concerned with the minimum level of funding necessary for operating and sustaining the asset base. Operating and sustaining the physical systems and components comprising facilities is a compulsory stewardship function, one that is inherent in ensuring the safety and integrity of physical structures and their environment. However, minimum funding levels often neglect existing backlog, which accordingly may grow to levels that necessitate premature facility replacement. Figure 5-2 shows this result conceptually, where the upper curve increases to a pre-determined value of the condition index, called replacement threshold. The point in time when the replacement threshold is exceeded represents the facility replacement cycle. Understanding and anticipating the consequences of a minimum funding strategy is therefore essential for effectively managing facilities condition.

Alternatively, facilities decision-makers are concerned with determining appropriate funding levels for reducing and eliminating current backlog, thereby improving facilities condition. Funding for current systems backlog, functional *improvement* needs, and capacity requirements is generally treated as discretionary activity. However, such investment is critical for sustaining the asset base over the long term and for aligning facilities layouts with operational demands. Projecting levels of requisite funding for addressing current backlog is thus necessary for effectively enhancing facilities condition and expanding facilities capacity.

Minimum funding represents a lower limit, or boundary, among the possible investment strategies, while maximum condition, or total elimination of backlog, defines an upper boundary. Figure 5-2 illustrates these conceptual, but practical, boundaries in terms of facilities condition over time. Depending on the level of funding discretion within these boundaries, facilities decision-makers may consider an array of strategies that reduce backlog to various levels and subsequently improve facilities condition to various states. In addition, facilities decision-makers must consider how quickly asset requirements can be executed, or at what pace investment can occur. Requirements are often interdependent due to facility space constraints and consequently must be phased over time. Hence, the pace of investment is driven not only by budget constraints, but also by practical restrictions on execution. Figure 5-2 also indicates the unlimited range of investment strategies that are associated with discretionary funding. Two such strategies are presented. The first maintains the baseline condition over time, while the second improves and maintains a target facilities condition.

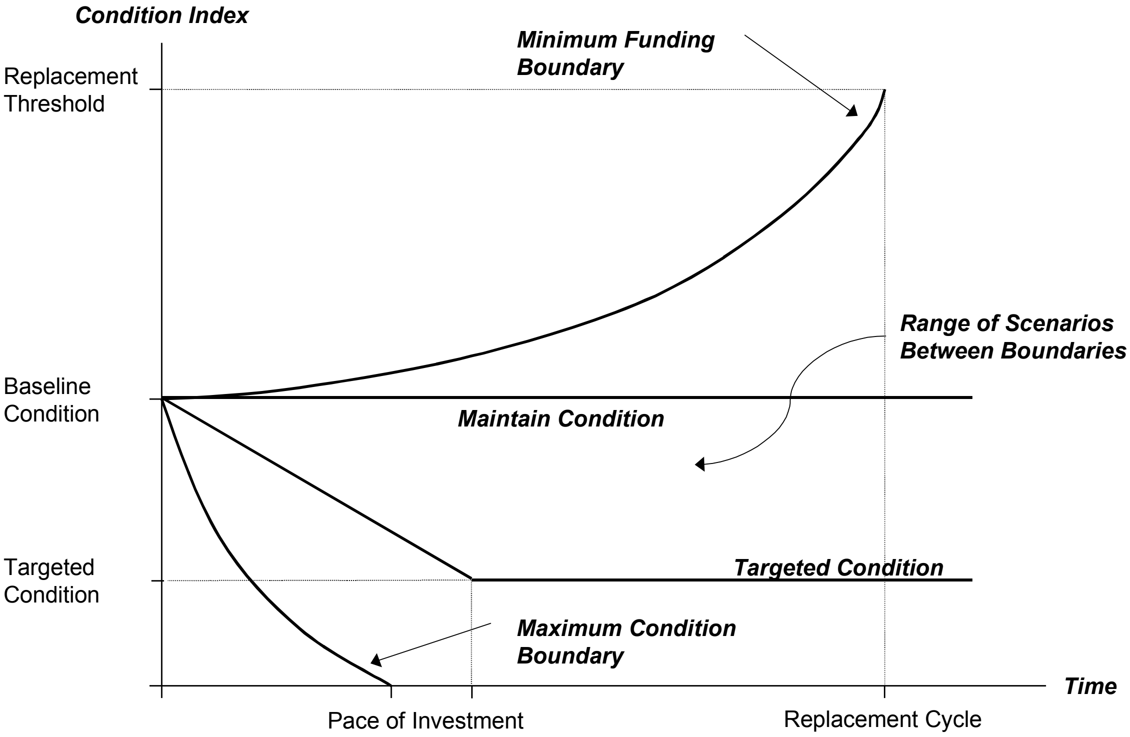


Figure 5-2 Conceptual Investment Strategies Defining Analysis Scenarios

In addition to contemplating the recapitalization of assets in-place, facilities decision-makers must consider the impact of acquisitions and dispositions on overall condition. When assets are considered as a portfolio, the addition of new facilities and the disposal of existing facilities effectively change current replacement value and total backlog, the essential elements for measuring facilities condition. Hence, the mix of assets is an important consideration in developing investment strategies.

Scenarios are developed based on these facility budgeting realities and concerns. Scenarios are defined and analyzed in four main sections: 1) boundary scenarios, 2) minimum funding scenarios, 3) discretionary funding scenarios, and 4) scenarios with new assets. Each section investigates how facilities decision-makers can effectively balance capital and condition, while considering other significant variables, such as pace of investment and mix of assets, within various degrees of budget constraint.

5.2.2 LEVEL OF ANALYSIS AND BASES OF COMPARISON

The analysis is conducted at an installation level. Facilities requirements, levels of capital commitment, and states of condition are aggregated within each scenario so that results represent the sum of facilities on an installation. The modeling tool permits the analysis of either a single facility or a portfolio of facilities, where the portfolio may comprise a single campus of facilities or a region of campuses. The installation level was chosen to demonstrate the capability of the modeling tool in supporting a comprehensive investment analysis. The overall funding and condition estimated at a portfolio level can readily be scaled to focus on a single facility, thus facilitating more detailed planning of where to concentrate investment.

Scenario results are analyzed at an aggregate level. Specifically, condition is represented by the comprehensive condition index, and annual funding is considered in total. For any given scenario, several, more revealing, details can be explored. For instance, the condition index can be viewed in terms of its technical, functional, and capacity components. Similarly, funding can also be divided into its constituent parts and considered as primary investment classes (i.e., *operations*, *sustainment*, *improvement*, *development*) or secondary investment classes (i.e., utilities, maintenance and repair, renewal, technical backlog, upgrades, alterations, additions, new and replacement facilities). Appendix D demonstrates facilities condition and funding details for select scenarios. Reviewing results at an aggregate level facilitates the analysis and comparison of multiple investment strategies.

The analysis presents condition results on an annual basis. That is, the condition index is displayed per period over 50 years. In contrast, funding is presented as uniform annual equivalents over a 10, 25, and 50-year horizon. Comparing projected funding per year for multiple scenarios poses a graphical challenge, and while relevant from budgeting perspective, neglects any consideration of the time value of money. The uniform annual equivalent conversion normalizes the otherwise “lumpy” funding cash flows and provides a theoretically more robust economic comparison of investment strategies. The three time horizons are selected for calculating the economic equivalents to illustrate the short, intermediate, and long-term effects on expenditure.

The 50-year outlook, while seemingly an unrealistically long vantage, captures the impact of the majority of facility systems requiring renewal. Of the 32 systems modeled for each facility, only two (exterior walls and structure) have an expected useful life exceeding 50 years. To illustrate the importance of viewing funding equivalents over different horizons, Figure 5-3 depicts projected system renewal requirements for a sample scenario. In this case, the 10-year annual equivalent would only capture funding up to the first large spike in year 2010. Similarly, the 25-year annual equivalent would only capture funding up to 2025, neglecting that beyond. Thus, the longer time horizons for calculating funding equivalents are more inclusive of future needs. On the other hand, the shorter time span equivalents are more representative of funding scenarios with large capital commitments in the initial years, and are likely more relevant for typical short-term budgeting perspectives. In cases where funding is level over time, the annual equivalent is equal to the uniform funding amount.

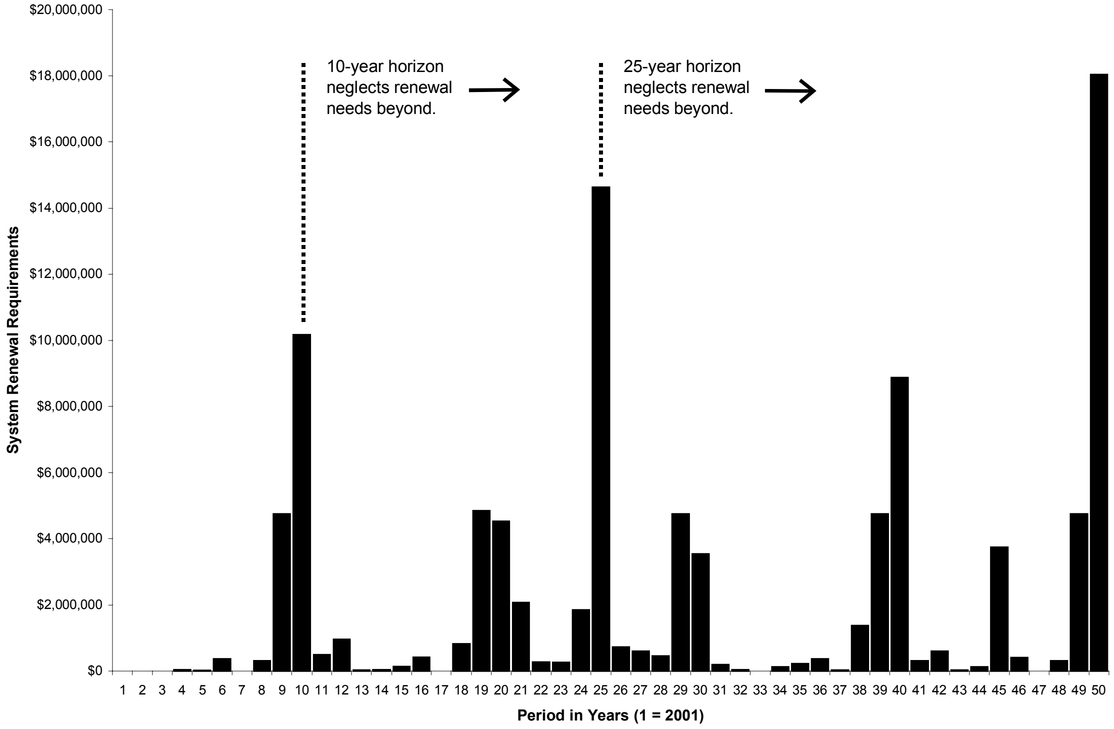


Figure 5-3 Renewal Requirements Forecast for Sample Scenario

5.3 Investigation of Boundary Scenarios

5.3.1 DEFINING THE BOUNDARY SCENARIOS

Boundary scenarios are developed based on the extremes of the two primary planning variables: capital and condition. The first scenario is the least aggressive in terms of capital investment. In this case, funds are allocated for operating and sustaining the facility portfolio, without enhancing condition and without adding new requirements to technical backlog. Funding is treated as the independent variable, while projected condition is the dependent variable. The remaining boundary scenarios treat funding in a discretionary sense and consider facilities condition the independent variable and capital the result. The second boundary scenario represents the "status quo," as it maintains the current facility condition over time. This scenario is similar to the first, except that some technical backlog is funded to offset growth beyond current levels. The next two scenarios are the most aggressive in terms of capital investment, as both pursue the maximum condition possible for enhancing the facilities portfolio. At this boundary, all known backlog is eliminated over two different time spans. A 5-year and a 10-year pace are selected as reasonable execution horizons given the useful life of the condition assessment and master plan data and typical budgeting time frames. Table 5-1 summarizes the boundary scenarios.

Budget Context	Scenario	No.	Description
Minimum	Minimum Funding	1	Operations and Sustainment are funded to match requirements; All backlog is unfunded
Discretionary	Maintain Condition	2	Operations and Sustainment are funded to match requirements; Technical backlog is level funded to maintain condition
	Maximum Condition (5 Yr)	3	Operations and Sustainment are funded to match requirements; Technical backlog is eliminated over 5 years; Improvement and Development are fully funded over 5 years
	Maximum Condition (10 Yr)	4	Operations and Sustainment are funded to match requirements; Technical backlog is eliminated over 10 years; Improvement and Development are fully funded over 10 years

Table 5-1 Descriptions of Boundary Scenarios

5.3.2 RESULTS AND ANALYSIS OF BOUNDARY SCENARIOS: PORTFOLIO I

Figure 5-4 shows the results of the forecasted condition per year for the four boundary scenarios. Scenario 1 minimally funds facility investment resulting in a progressive deterioration of condition over time. In 48 years, the cumulative backlog increases beyond 75% of the current replacement value (i.e., condition index is 0.75), thereby exceeding the selected replacement threshold. Scenario 2 simply maintains the current condition index at 0.39 by containing the growth of technical backlog with level funding. In this scenario, the condition index in period 50 is equated to that in period 0 and the resulting level funding for technical backlog determined. Scenario 3 and Scenario 4 result in a rapid improvement of condition by eliminating all technical, functional, and capacity backlogs. Scenario 3 eliminates backlog over 5 years, while Scenario 4 does so over 10 years.

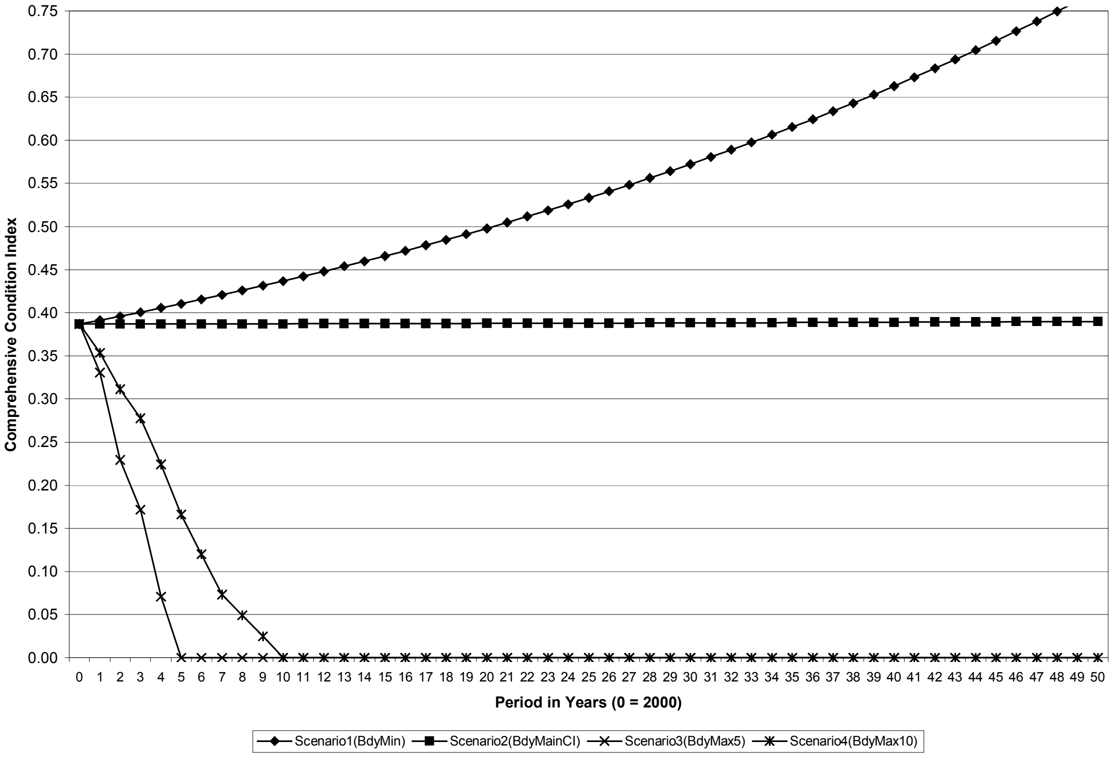
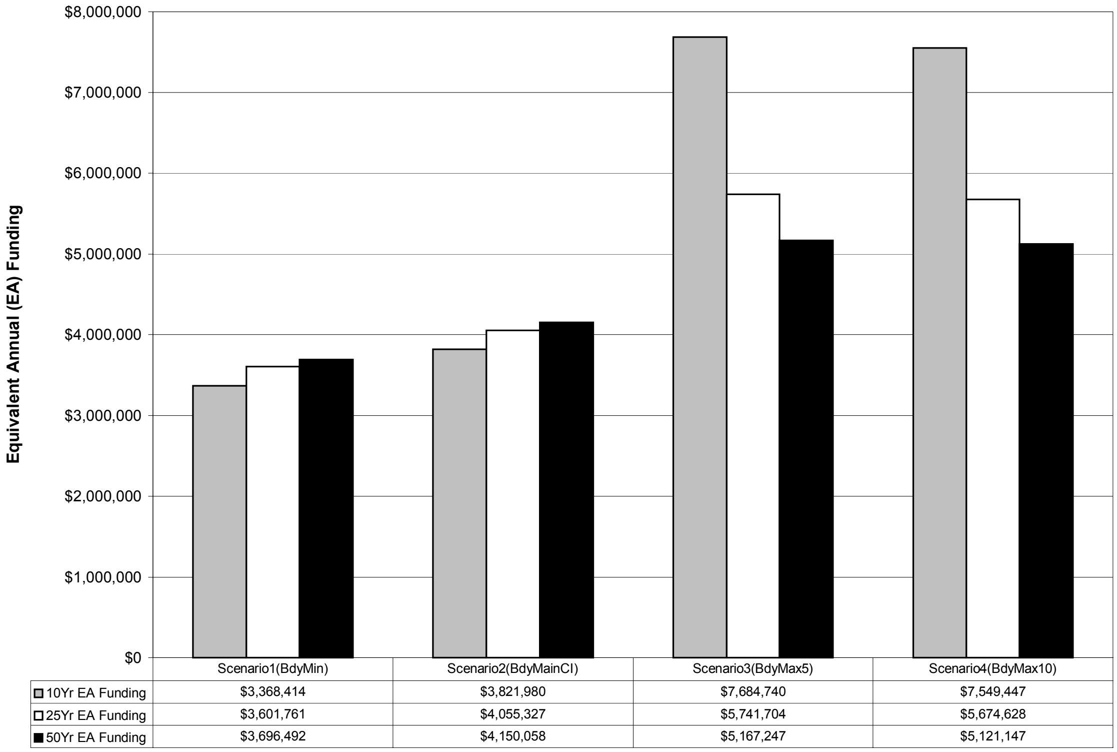


Figure 5-4 Projected Comprehensive Condition Indices for Boundary Scenarios (Fort Belvoir)

While the outcome of the latter two scenarios is a much improved condition posture relative to the first two scenarios, the results come at a notable difference in expenditure. Figure 5-5 compares the equivalent annual funding for each scenario. It is evident from the figure that over the short term Scenario 1 and Scenario 2 require substantially less in equivalent annual funding, nearly $4 million less than Scenario 3 and Scenario 4. However, over the intermediate and long term, the funding gap diminishes substantially, as more renewal expenditure is included (driving funding for Scenarios 1 and 2 upward) and the initial investment in backlog (Scenarios 3 and 4) is dispersed over many more periods. Over the long term, Scenario 1 and Scenario 2 are separated by some $450,000, while Scenarios 3 and 4 are roughly $1 million greater than Scenario 2.



	Scenario1(BdyMin)	Scenario2(BdyMainCI)	Scenario3(BdyMax5)	Scenario4(BdyMax10)
▨ 10Yr EA Funding	$3,368,414	$3,821,980	$7,684,740	$7,549,447
☐ 25Yr EA Funding	$3,601,761	$4,055,327	$5,741,704	$5,674,628
■ 50Yr EA Funding	$3,696,492	$4,150,058	$5,167,247	$5,121,147

Figure 5-5 Equivalent Annual Funding for Boundary Scenarios (Fort Belvoir)

5.3.3 RESULTS AND ANALYSIS OF BOUNDARY SCENARIOS: PORTFOLIO II

Projected annual condition results for Portfolio II (Fort Stewart) are shown in Figure 5-6. In this portfolio, the minimum funding scenario (Scenario 1) follows a less debilitating path than that of Portfolio I. The final condition index at period 50 is 0.41, and thus does not exceed the replacement threshold. This distinction among the portfolios is attributable to the baseline condition in period 0. Portfolio II starts at an initial condition index of 0.21, while Portfolio I begins at a worse condition state (index value of 0.39). Scenario 2 maintains the initial index value at 0.21 up to period 50. Scenario 3 and Scenario 4 maximize condition over five and ten years, respectively, by eliminating the totality of backlog. It should be noted that Scenario 3 actually occurs over a 6-year span due to the interdependency of *improvement* projects.

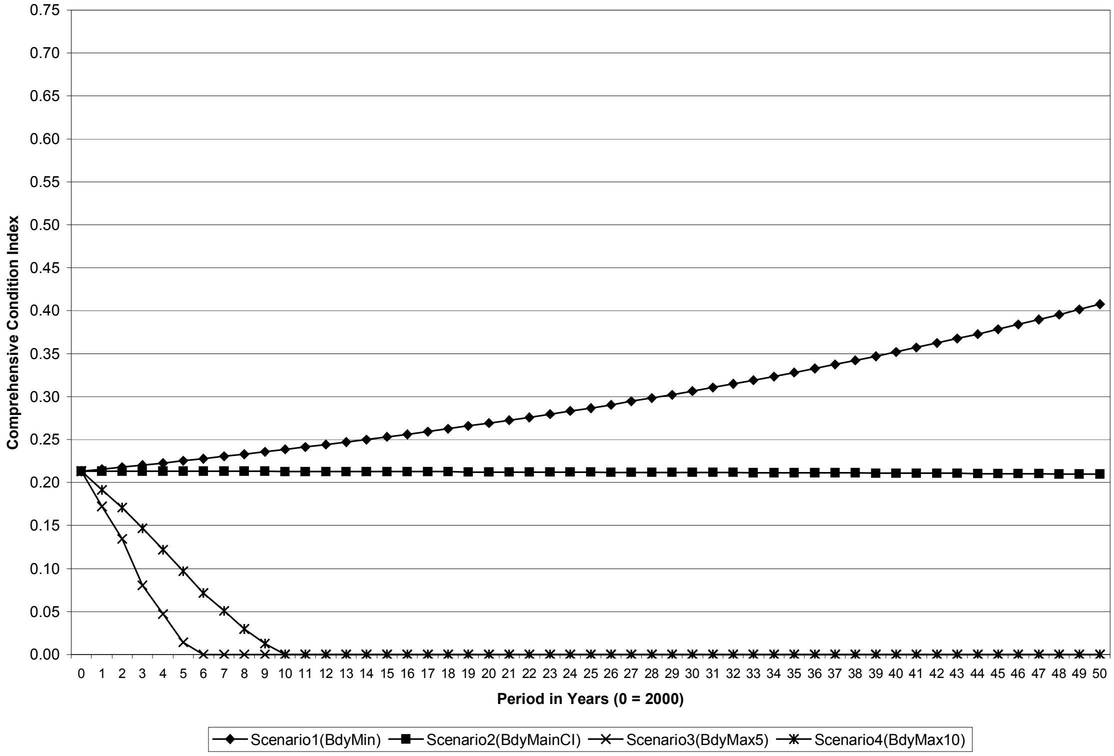
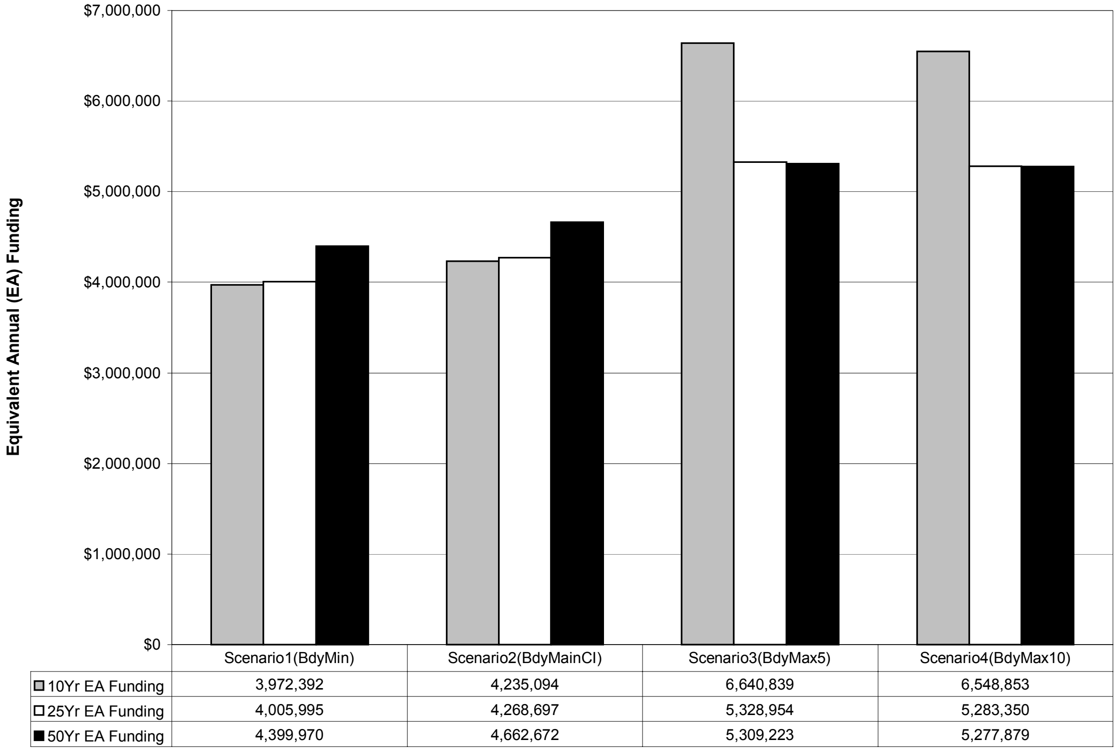


Figure 5-6 Projected Comprehensive Condition Indices for Boundary Scenarios (Fort Stewart)

As shown in Figure 5-7, the funding disparity among the boundary scenarios is also less pronounced. Over the three time horizons, the equivalent annual funding difference between Scenario 1 (minimum funding scenario) and Scenario 2 (maintain condition scenario) is approximately $260,000, or 6%. Hence, a marginal increase in the minimum funding level can maintain the current condition of health facilities at Fort Stewart. The maximum condition scenarios (Scenarios 3 and 4) exceed Scenario 2 by nearly $2.4 million in funding over ten years, $1 million over 25 years, or $600,000 over fifty years. Thus from a long-term vantage, the difference between deteriorating facilities and maximum condition is less than $1 million in annual funding, or roughly 20%.



	Scenario1(BdyMin)	Scenario2(BdyMainCl)	Scenario3(BdyMax5)	Scenario4(BdyMax10)
▨ 10Yr EA Funding	3,972,392	4,235,094	6,640,839	6,548,853
☐ 25Yr EA Funding	4,005,995	4,268,697	5,328,954	5,283,350
■ 50Yr EA Funding	4,399,970	4,662,672	5,309,223	5,277,879

Figure 5-7 Equivalent Annual Funding for Boundary Scenarios (Fort Stewart)

5.4 Investigation of Minimum Funding Scenarios

5.4.1 DEFINING MINIMUM FUNDING SCENARIOS

Minimum investment scenarios are developed to explore the gradations of the minimum-funding boundary further. Each of the scenarios in Table 5-2 funds utilities and maintenance and repair as required. System renewal funding is then varied from zero to a percentage of the portfolio replacement value, in incremental steps. This value-based approach is a common budgeting practice for facility sustainment (Ottoman et al. 1999), one also used by Army health facility planners (Sartori and Arnold 1997). Scenario 5 adjusts the minimum-funding scenario (Scenario 1) by excluding renewal funding. It is included to examine the result of not replacing systems when needed. Scenarios 6, 7, and 8 then apply level renewal funding at 0.5%, 1.0%, and 1.5% of replacement value, respectively. In years when available renewal funds exceed projected requirements, the overage is used to decrement technical backlog. Correspondingly, under funded requirements are added to existing technical backlog.

Scenario	No.	Description
Minimum Funding w/out Renewal	5	Operations and Maintenance and repair are funded to match requirements; Renewal and all backlog is unfunded
Level Renewal Funding @ 0.5% CRV	6	Operations and Maintenance and repair are funded to match requirements; Renewal funded at a level 0.5% CRV; Overage applied to technical backlog; Improvement and Development is unfunded
Level Renewal Funding @ 1.0% CRV	7	Operations and Maintenance and repair are funded to match requirements; Renewal funded at a level 1.0% CRV; Overage applied to technical backlog; Improvement and Development is unfunded
Level Renewal Funding @ 1.5% CRV	8	Operations and Maintenance and repair are funded to match requirements; Renewal funded at a level 1.5% CRV; Overage applied to technical backlog; Improvement and Development is unfunded

Table 5-2 Descriptions of Minimum Funding Scenarios

5.4.2 RESULTS AND ANALYSIS OF MINIMUM FUNDING SCENARIOS: PORTFOLIO I

Projected condition results for the minimum funding scenarios, including the boundary scenario (Scenario 1), are presented in Figure 5-8. The scale of the vertical axis representing condition index values is limited at the top by the selected replacement threshold, which is 75%. The replacement threshold is more evident (relative to the boundary scenarios) among these minimum-funding scenarios, as the technical backlog increases unrestrained over time. The combination of new renewal requirements and the steady growth of existing backlog cause each scenario to exceed the replacement threshold prior to the 50-year mark. Scenario 5 reaches the threshold the quickest at period 19, while Scenario 8 reaches the slowest at period 40. The threshold period for each scenario is summarized and denoted as replacement cycle in Table 5-3. The scenarios progressively diverge from the current condition index of 0.39 in a similar pattern. Each oscillates between steeply rising and steadily declining conditions, which are driven by the annual differences between renewal needs and funding. Periods in which renewal is not sufficiently funded are apparent from the sharp increases in the condition index. This occurs in periods 9 and 10, 19 and 20, 25, 29 and 30, and 39 and 40.

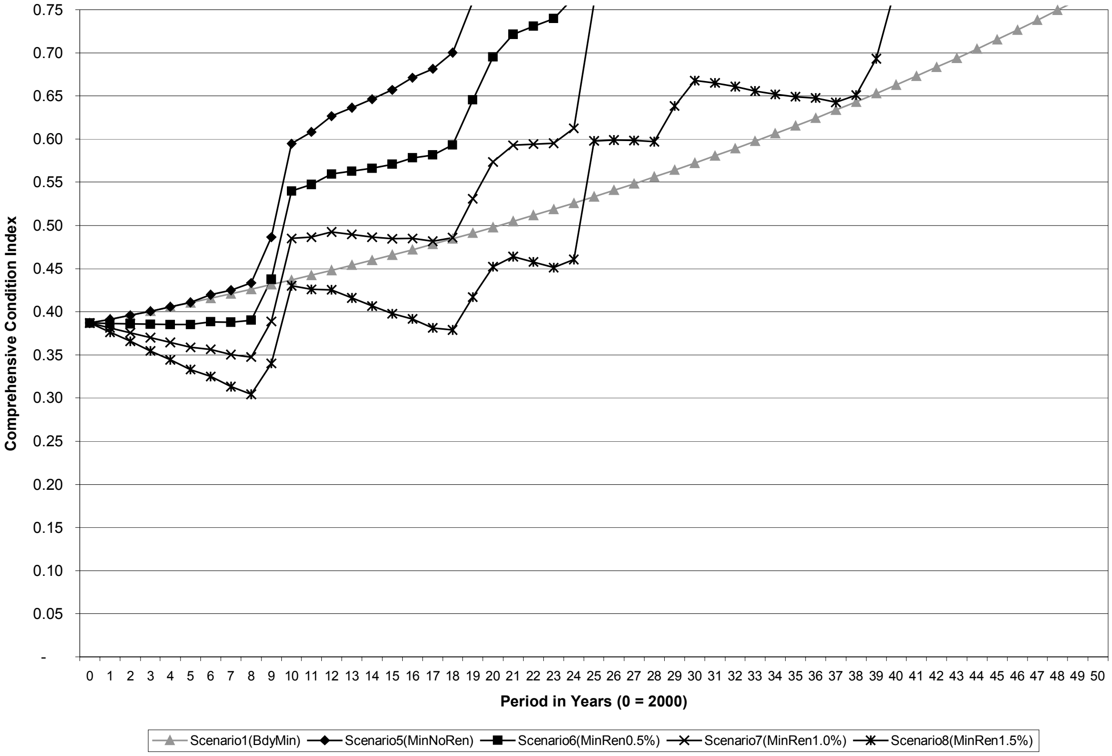


Figure 5-8 Projected Comprehensive Condition Indices for Minimum Funding Scenarios (Fort Belvoir)

It is evident from Figure 5-8 that over the long run, the policy of funding renewal requirements as they come due results in the most manageable strategy among minimum-funding scenarios. This strategy, represented by Scenario 1, provides a stable condition posture over time and affords the best outcome over a long time. However over shorter horizons, level funding of renewal results in better, but less stable, annual condition indices. Scenario 8 provides a better (relative to Scenario 1) condition posture up to year 2025, and Scenario 6 and 7 appear better through year 2009. It should be noted that these conclusions are specific to Portfolio I (Fort Belvoir) and are attributable mainly to this portfolio's unique renewal requirements and existing backlog.

The difference in expenditure among the minimum-funding scenarios is summarized in Table 5-3. The different time horizons for calculating equivalent annual funding are irrelevant for the level funding scenarios, as the equivalent annual funding is equal to the level amount over any chosen horizon. In the case of Scenario 1, the funding levels represent the amount of investment in renewal or that saved for future renewal over 50 years. Scenarios 5 through 8 differ by approximately $500,000 in terms of annual funding, while Scenario 1 is roughly $200,000 more than Scenario 8 over 50 years.

Scenario	Equivalent Annual Funding	Replacement Cycle
1	(10 Yr) $3,368,414 (25 Yr) $3,601,761 (50 Yr) $3,696,492	48
5	$1,996,753	19
6	$2,497,022	24
7	$2,997,291	25
8	$3,497,560	40

Table 5-3 Equivalent Annual Funding and Replacement Cycles for Minimum Funding Scenarios (Fort Belvoir)

5.4.3 RESULTS AND ANALYSIS OF MINIMUM FUNDING SCENARIOS: PORTFOLIO II

Figure 5-9 displays forecasted conditions for minimum funding scenarios in Portfolio II. As in Portfolio I, these scenarios result in backlog growth that exceeds 75% of the portfolio replacement value prior to period 50, with the exception of Scenario 1. Scenario 5 reaches the replacement threshold in 23 years, while Scenario 8 does so in 48 years. Each scenario also diverges from the current condition index of 0.21 in a similar pattern, which again is attributable to projected renewal requirements. However, the rate of increase is somewhat less than Portfolio I, since the initial backlog is less and the renewal profile is more distributed (i.e., renewal requirements are less concentrated and occur over more periods).

Beyond period 10, Scenario 1, which funds renewal needs as they come due, provides the most stable condition posture and the best outcome among the minimum funding scenarios. Prior to period 10, Scenarios 6, 7, and 8 improve the condition index to levels lower than Scenario 1. However, these scenarios increase dramatically in periods 8 and 10 as substantial renewal requirements begin to outstrip level funding policies. In all periods, the strategy of not funding renewal needs results in rapid facility deterioration. Scenario 5 represents this strategy, which clearly results in the worst condition index over each period.

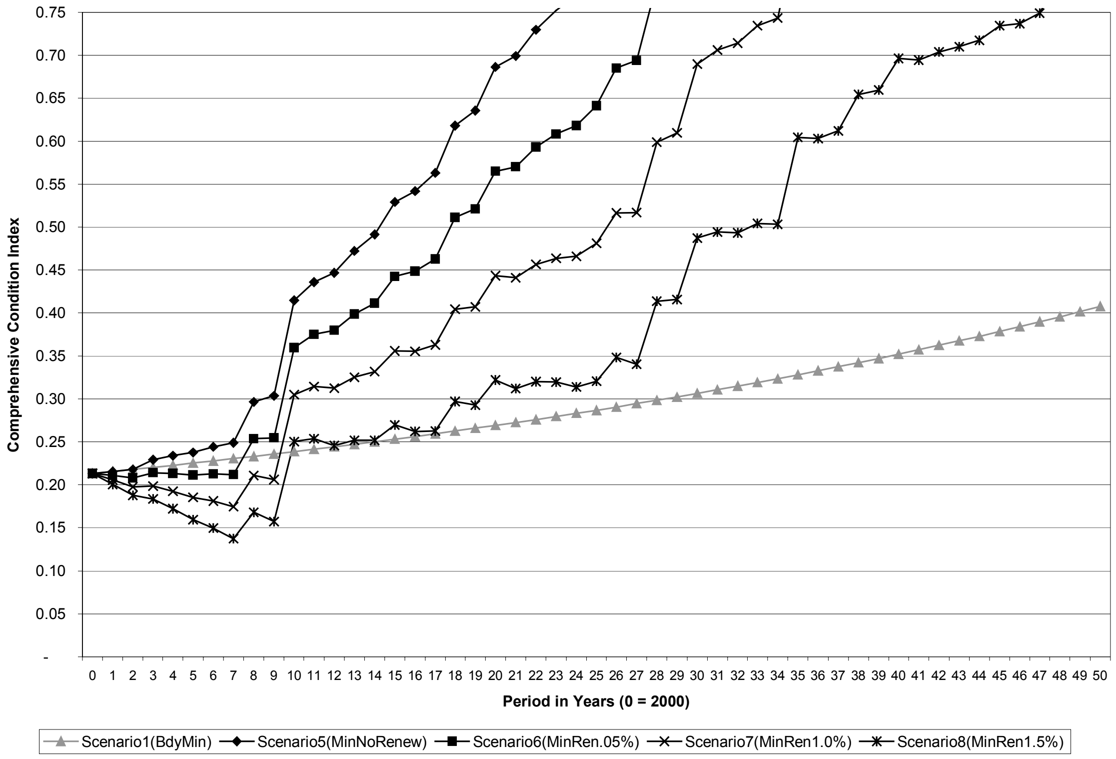


Figure 5-9 Projected Comprehensive Condition Indices for Minimum Funding Scenarios (Fort Stewart)

Projected replacement cycles and funding are summarized in Table 5-4. The level funding scenarios (Scenarios 5 through 8) differ in annual funding by about $562,000. Equivalent annual funding for Scenario 1 exceeds Scenario 8 levels by nearly $50,000 over the short-term and by roughly $477,000 over the long-term. Again, Scenario 1 includes more renewal needs over the longer time horizon leading to the increase in funding.

Scenario	Equivalent Annual Funding	Replacement Cycle
1	(10 Yr) $3,972,392 (25 Yr) $4,005,995 (50 Yr) $4,399,970	88
5	$2,236,196	23
6	$2,798,621	28
7	$3,361,047	35

8	$3,923,472	48

Table 5-4 Equivalent Annual Funding and Replacement Cycles for Minimum Funding Scenarios (Fort Stewart)

5.5 Investigation of Discretionary Funding Scenarios

5.5.1 DEFINING DISCRETIONARY FUNDING SCENARIOS

Discretionary funding scenarios focus on existing facilities, and they are developed to explore the various condition states that can be achieved when investment is treated flexibly. When funding is regarded in an unrestricted manner, condition and pace of investment emerge as the two primary independent variables. Backlog is then funded at a variable pace to achieve a desired state of condition. However, simply reaching a target condition is often not the end objective; in many cases, the goal is to maintain that target posture once attained. In addition, investment in facility backlog is often focused exclusively on building systems (technical backlog) with minimal regard for the backlog of functional and capacity needs. Scenarios are developed in this section to examine the impact on funding from the following: 1) improving condition to different target states, 2) investing at different rates, 3) maintaining the target condition after it is reached, and 4) concentrating investment on technical backlog.

Three different target condition values (expressed in terms of the condition index) are used in the analysis to explore the degrees of funding required to incrementally improve condition. Target values are slightly different for the two portfolios, since each has a different baseline condition. The initial (period 0) condition index for Portfolio I is 0.39; Portfolio II starts at 0.21. The three target values selected for Portfolio I are 0.05, 0.15, and 0.25, and the values for Portfolio II are 0.05, 0.10, 0.15. Funding is modeled to reduce backlog to levels that achieve these target values. In each scenario, functional and capacity backlog is reduced to zero, and the requisite funding is modeled according to the interdependence of identified requirements. Funding for functional and capacity backlog is therefore not uniform. Funding for technical backlog is modeled as a level cash flow and is effectively treated as the dependent variable.

Consistent with the boundary scenarios, the pace of investment is modeled over a 5-year and 10-year horizon. These rates are selected because of the limited useful life of the condition assessment and master planning data. The information from these two studies is generally considered practical up to only a few years before reassessment is warranted. Moreover, the requirements identified in these studies are often interdependent and must be executed in phases, which, as is the case in the two portfolios being analyzed, may take a minimum number of years. Furthermore, the volume of backlog identified may exceed practical budgeting limits over short time frames. Hence, the rate of investment may be slower (and the investment horizon longer) to accommodate both budgeting and execution phasing realities.

Table 5-5 describes the discretionary funding scenarios. Scenarios 9 through 15 achieve facility condition targets over a 5-year horizon, while Scenarios 16 through 22 do so over 10 years. Scenarios 11, 13, 15, 18, 20, and 22 maintain the target condition once attained, while the others simply reach a target state and discontinue funding backlog thereafter. Scenarios 9 and 16 investigate the impact on condition when funding only technical backlog, without regard for functional and capacity backlog. Recall that the maximum condition boundary scenarios (Scenarios 3 and 4) fund total backlog; however, Scenarios 9 and 16 are intended to demonstrate the impact of concentrating solely on building systems.

Scenario	**Scenario No.**		**Description**
	5 Year Pace	10 Year Pace	
Maximum Condition (Technical Backlog Only)	9	16	Operations and Sustainment are funded to match requirements; Technical backlog is eliminated with level funding; Improvement and Development is unfunded
Target Condition 0.05	10	17	Operations and Sustainment are funded to match requirements; Technical backlog is level funded to achieve comprehensive condition index = .05 over 5 or 10 years; Improvement and Development are fully funded
Target Condition 0.05 + Maintain	11	18	Operations and Sustainment are funded to match requirements; Technical backlog is level funded to achieve comprehensive condition index = .05 over 5 or 10 years; Improvement and Development are fully funded; Technical backlog is funded to maintain condition over 50 years
Target Condition 0.15 (0.10 for Portfolio II)	12	19	Operations and Sustainment are funded to match requirements; Technical backlog is level funded to achieve comprehensive condition index = .15 over 5 or 10 years; Improvement and Development are fully funded
Target Condition 0.15 (0.10 for Portfolio II) + Maintain	13	20	Operations and Sustainment are funded to match requirements; Technical backlog is level funded to achieve comprehensive condition index = .15 over 5 or 10 years; Improvement and Development are fully funded; Technical backlog is funded to maintain condition over 50 years
Target Condition .025 (0.15 for Portfolio II)	14	21	Operations and Sustainment are funded to match requirements; Technical backlog is level funded to achieve comprehensive condition index = .25 over 5 or 10 years; Improvement and Development are fully funded

Target Condition 0.25 (0.15 for Portfolio II) + Maintain	15	22	Operations and Sustainment are funded to match requirements; Technical backlog is level funded to achieve comprehensive condition index = .25 over 5 or 10 years; Improvement and Development are fully funded; Technical backlog is funded to maintain condition over 50 years

Table 5-5 Descriptions of Discretionary Funding Scenarios

5.5.2 RESULTS AND ANALYSIS OF DISCRETIONARY FUNDING SCENARIOS: PORTFOLIO I

Figure 5-10 presents projected condition results for the discretionary funding scenarios (Scenarios 9 through 15) based on a 5-year pace of investment. Figure 5-11 shows condition results for the scenarios (Scenarios 16 through 22) with a 10-year investment rate. The analysis begins with a discussion of general observations and then examines targeted condition states and the disparity between simply reaching a preferred condition posture and maintaining that posture.

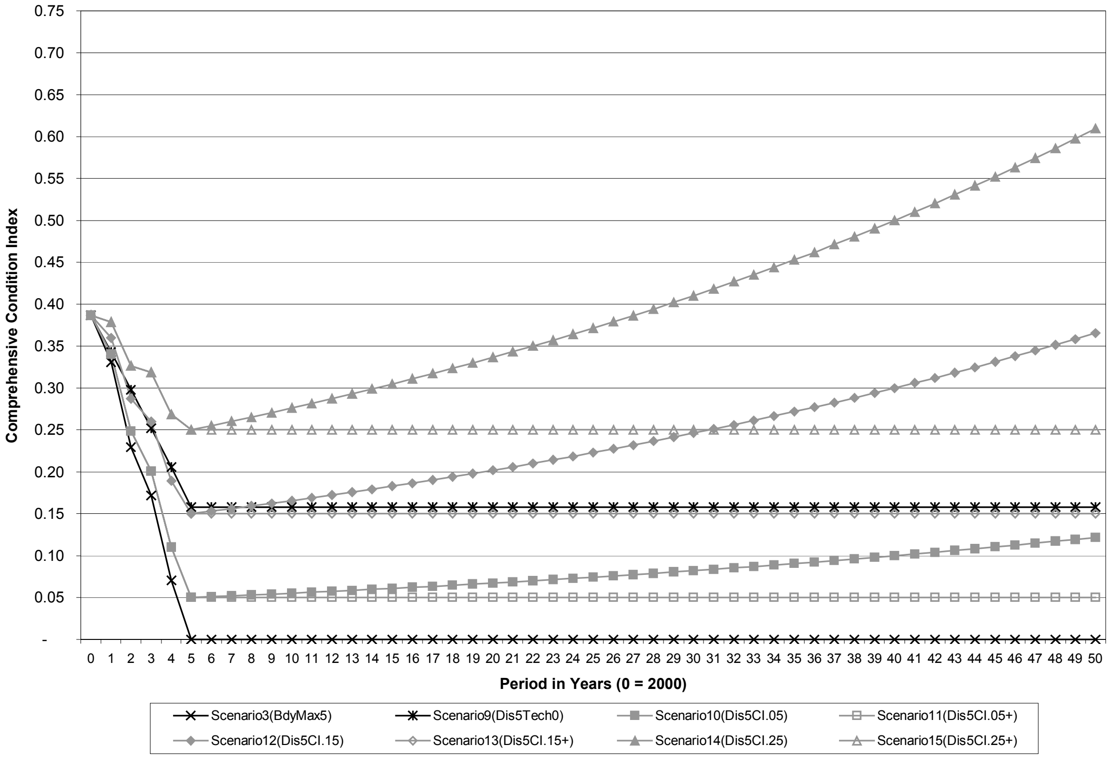


Figure 5-10 Projected Comprehensive Condition Indices for Discretionary Funding Scenarios at 5-year Pace (Fort Belvoir)

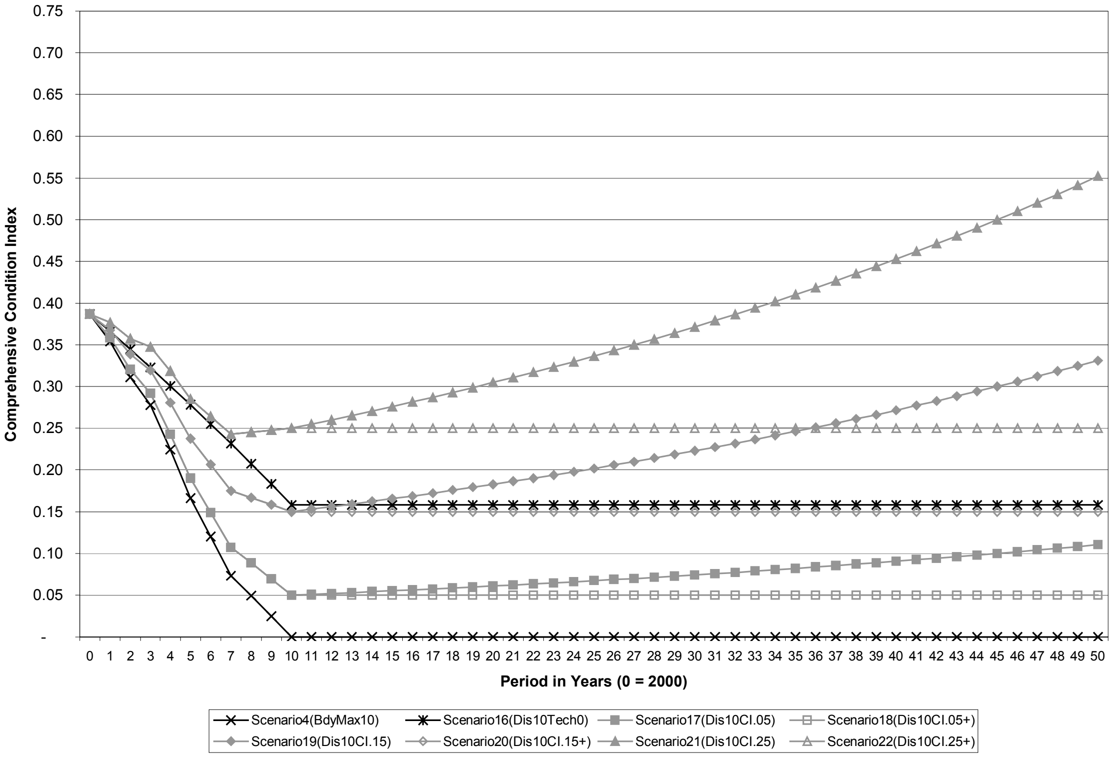


Figure 5-11 Projected Comprehensive Condition Indices for Discretionary Funding Scenarios at 10-year Pace (Fort Belvoir)

One observation common to all of the scenarios is that the replacement threshold is never reached over a 50-year horizon, since each effectively reduces backlog to varying levels. The second common observation is that the condition profile over the initial five to ten years (up to the period that attains the targeted condition index value) follows an indirect path, as *improvement* and *development* requirements are not level funded. Finally, the condition posture diverges from the target state (when not maintained) at a much steeper rate for higher index values, since these higher values are associated with larger volumes of backlog growing at a constant rate. For example, Figure 5-10 shows how Scenario 10 diverges away from Scenario 11 at a less severe rate, while Scenario 14 makes a much sharper ascent from Scenario 15. Figure 5-11 illustrates the same for Scenarios 18 through 23.

The final observation suggests that better condition states are more cost effective to manage and maintain over long periods, as they deteriorate more slowly over long horizons. This observation is further evident in Figure 5-12, which displays only technical backlog funding over 25 years for select scenarios. Funding for those scenarios that achieve and maintain a targeted condition state are shown to illustrate that larger initial investment in backlog requires less outlay to maintain the condition state. Scenario 18 and Scenario 20 invest nearly $2.1 million and $1.2 million per year, respectively, over the first 10 years to reduce technical backlog. Consequently, these two scenarios require merely $100,000 and $300,000, respectively, over the remaining years to maintain technical backlog at desired levels. The counterpoint is represented by Scenario 22, which reduces technical backlog over the initial 10 years by $260,000 annually and requires double that amount to maintain the condition posture beyond.

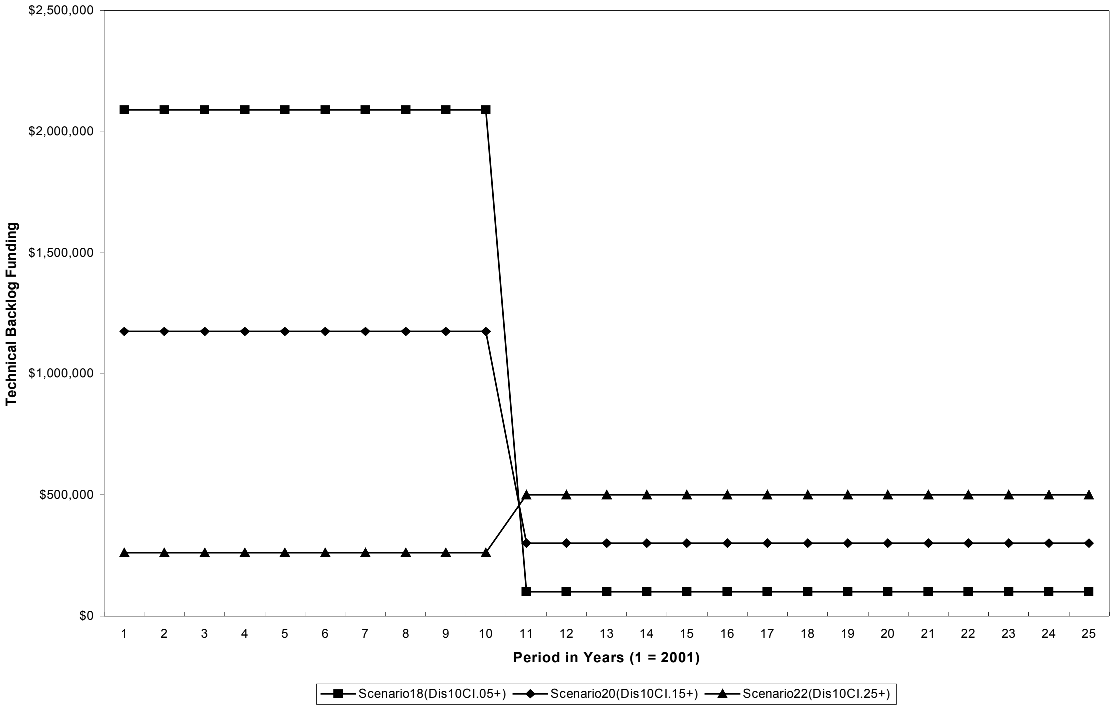
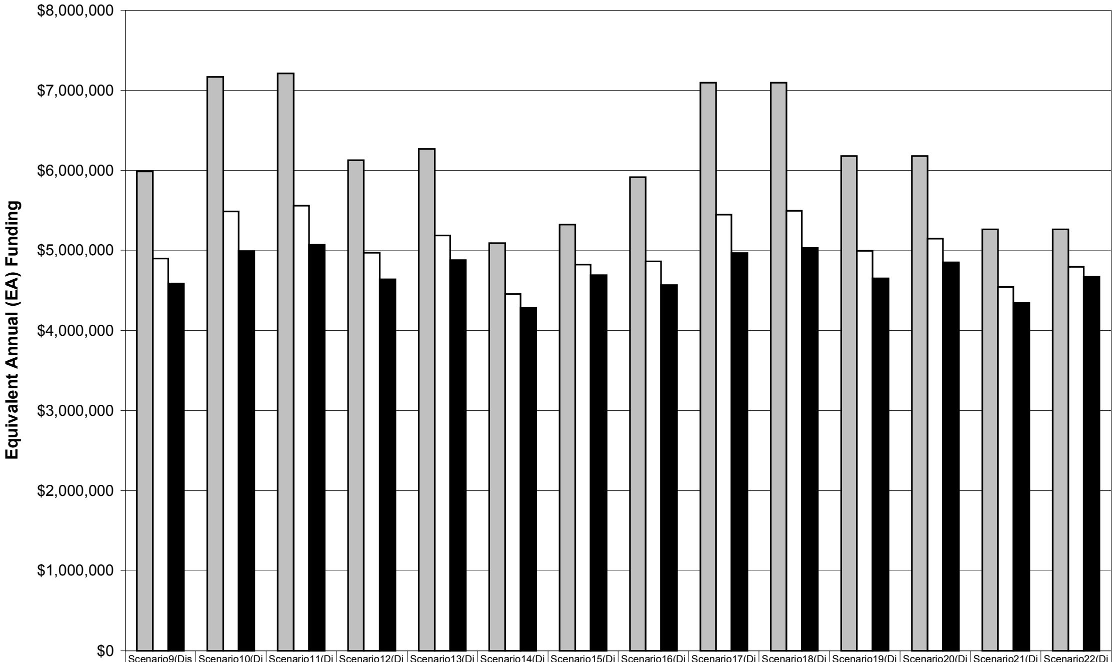


Figure 5-12 Forecasted Funding of Technical Backlog for Scenarios that Maintain Targeted Condition (Fort Belvoir)

The condition results also suggest that simply focusing on technical backlog does not allay the condition posture entirely, as functional and capacity backlog remains. Scenario 9 and Scenario 16 fund technical backlog exclusively and contrast with the maximum condition scenarios (Scenarios 3 and 4), which fund all backlog. Since functional and capacity requirements are modeled without growth, it appears that Scenarios 9 and 16 reach and maintain a final condition state very similar to Scenarios 13 and 20. However, the investment strategies are much different. The latter two scenarios fully fund *improvement* and *development* projects and fund technical backlog at a level amount to reach the objective condition state. The former two scenarios disregard the functional and capacity aspects of the facility portfolio, yet they do not result in further obsolescence. Until such time that obsolescence rates can be determined and functional and capacity backlog subsequently modeled as expanding, it will appear (as is currently modeled) that funding technical backlog as a priority may prove a better strategy. This should be considered a limitation of the modeling effort, as well as the supporting body of knowledge, which to date is not suggestive of how to model functional decay.

Equivalent annual funding for the discretionary investment scenarios is compared in Figure 5-13. The most costly strategy is Scenario 11, while the least costly strategy is Scenario 14. These two scenarios represent the best and worst condition postures among the discretionary investment scenarios, and both are executed at a 5-year pace. The range of funding varies from approximately $7.2 million to $5.1 million for the 10-year annual equivalent horizon. As the annual equivalent horizon increases, this range diminishes.



	Scenario9(Dis 5Tech0)	Scenario10(Di s5CI.05)	Scenario11(Di s5CI.05+)	Scenario12(Di s5CI.15)	Scenario13(Di s5CI.15+)	Scenario14(Di s5CI.25)	Scenario15(Di s5CI.25+)	Scenario16(Di s10Tech0)	Scenario17(Di s10CI.05)	Scenario18(Di s10CI.05+)	Scenario19(Di s10CI.15)	Scenario20(Di s10CI.15+)	Scenario21(Di s10CI.25)	Scenario22(Di s10CI.25+)
▨ 10Yr EA Funding	$5,985,279	$7,166,314	$7,212,410	$6,129,461	$6,267,748	$5,092,609	$5,323,087	$5,914,633	$7,092,568	$7,092,568	$6,178,812	$6,178,812	$5,265,055	$5,265,055
☐ 25Yr EA Funding	$4,899,147	$5,484,679	$5,557,981	$4,970,629	$5,190,537	$4,456,580	$4,823,092	$4,864,122	$5,448,117	$5,498,567	$4,995,096	$5,146,444	$4,542,075	$4,794,322
■ 50Yr EA Funding	$4,588,169	$4,990,597	$5,072,265	$4,637,298	$4,882,302	$4,283,998	$4,692,338	$4,564,097	$4,965,469	$5,031,430	$4,654,114	$4,851,997	$4,342,758	$4,672,564

Figure 5-13 Equivalent Annual Funding for Discretionary Funding Scenarios (Fort Belvoir)

Over the 25-year equivalent horizon, Scenario 11 and Scenario 14 vary between $5.6 million and $4.5 million, respectively, and over the 50-year horizon, the difference is $5.1 million and $4.3 million. Relative to the boundary scenario (Scenario 3), Scenario 11 requires roughly 7% ($7.2 million vis-à-vis $7.7 million) less investment over 10 years, and the margin decreases to roughly $100,000 per year over 25 and 50 years.

5.5.3 RESULTS AND ANALYSIS OF DISCRETIONARY FUNDING SCENARIOS: PORTFOLIO II

Condition projections for the discretionary funding scenarios are shown in Figure 5-14 for those executed at a 5-year investment pace and Figure 5-15 for those funded at a 10-year pace. The common observations discussed in Portfolio I are also reflected in these figures. That is, the replacement threshold is not reached over a 50-year timeframe, condition improvement follows an indirect path up to the targeted index value, and condition indices diverge from the target value (when not maintained) at a steeper rate for higher index values (or worse states of condition). Furthermore, it is evident that exclusive emphasis on funding facility systems addresses only part of the condition

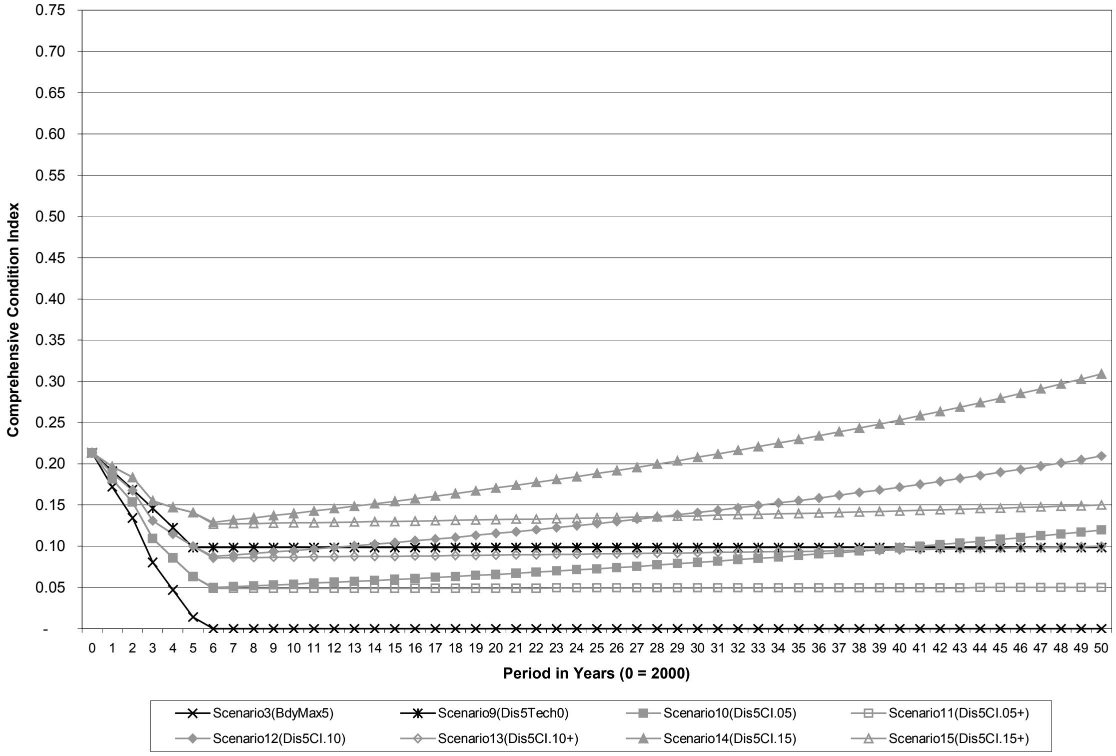


Figure 5-14 Projected Comprehensive Condition Indices for Discretionary Funding Scenarios at 5-year Pace (Fort Stewart)

problem. Similar to Portfolio I, Scenario 9 and Scenario 16 eliminate all technical backlog only to achieve a condition state similar to Scenario 13 and Scenario 20. The former two scenarios are limited in the degree to which they affect the overall portfolio condition, since functional and capacity backlog is not taken into account.

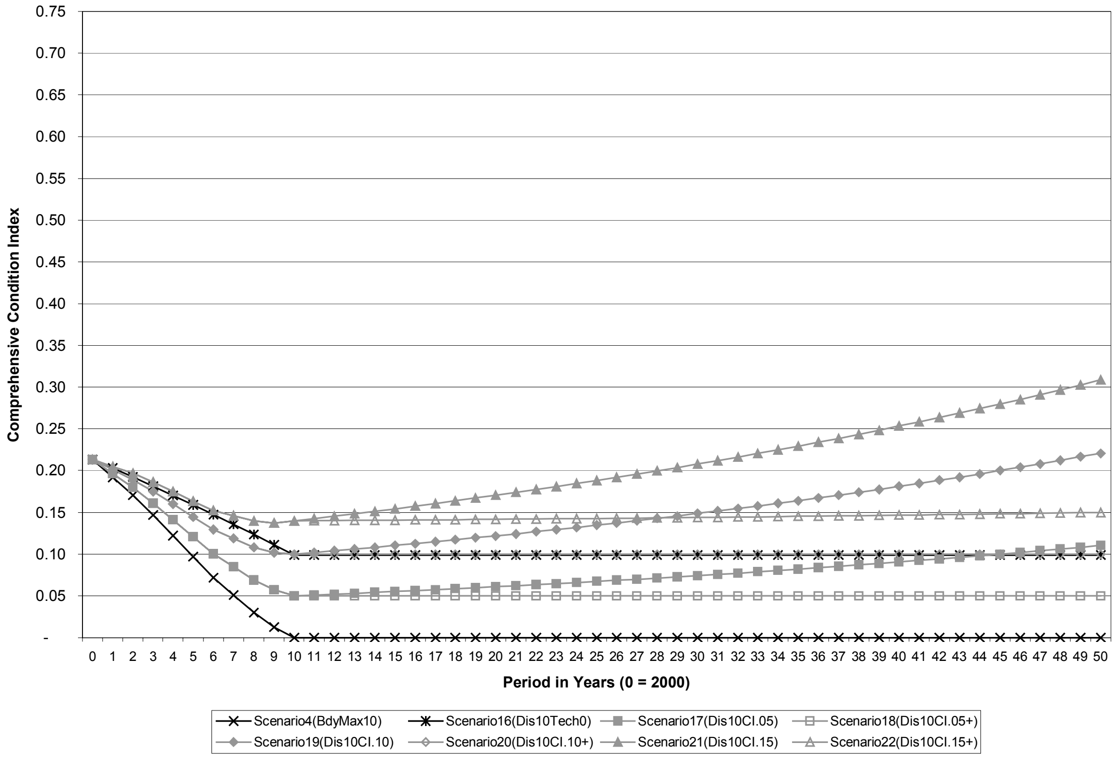


Figure 5-15 Projected Comprehensive Condition Indices for Discretionary Funding Scenarios at 10-year Pace (Fort Stewart)

The condition states in Portfolio II behave somewhat different from those in Portfolio I, as the interdependent *improvement* requirements permit an execution pace of no less than six years. This subtlety is particularly evident in Figure 5-14, where desired condition levels are attained over five years. Funding for technical backlog is still modeled over a 5-year horizon, so that the functional backlog executed in period 6 actually drives the condition index slightly below the target value. Scenarios 12 through 15 highlight this point. Additionally, Scenario 14 and Scenario 15 are able to achieve the target condition value of 0.15 by executing only *improvement* and *development* projects in the initial five years. Technical backlog is then funded in the remaining periods to prevent the condition index from growing beyond the target value in period 50. Figure 5-16 illustrates funding of technical backlog for select scenarios. Similar to Portfolio I, this figure indicates that lower levels of funding at the outset necessitate higher funding levels later to maintain desired states of condition and vice versa.

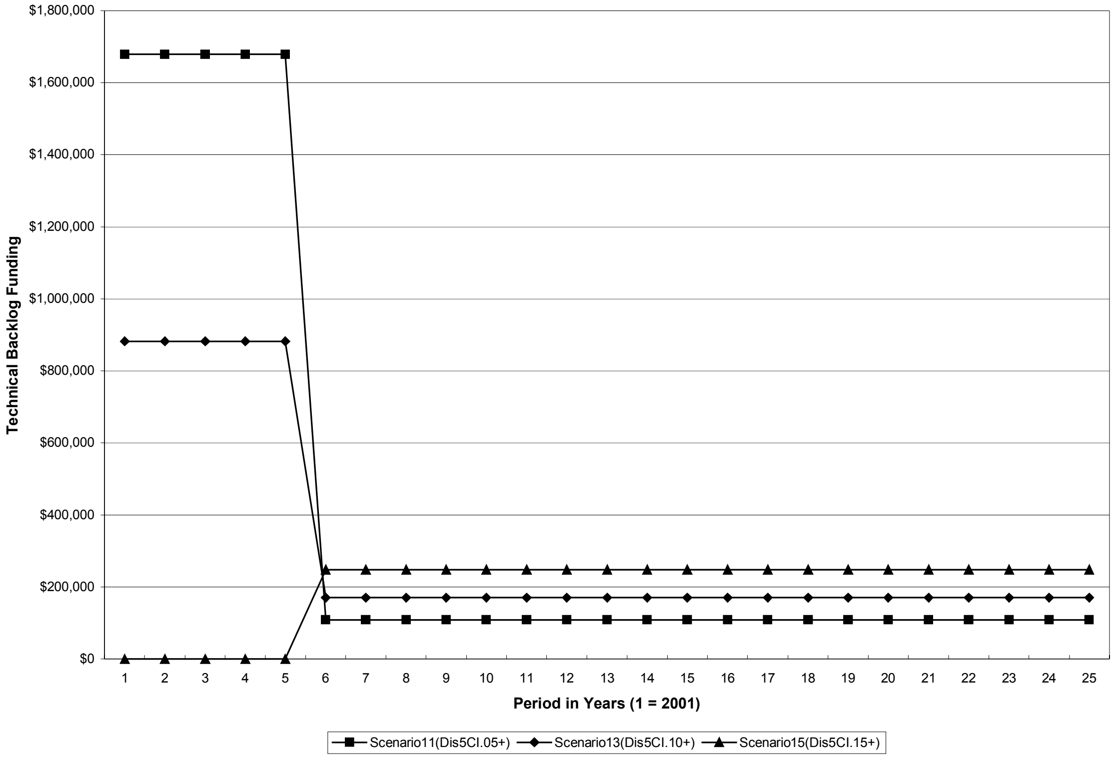
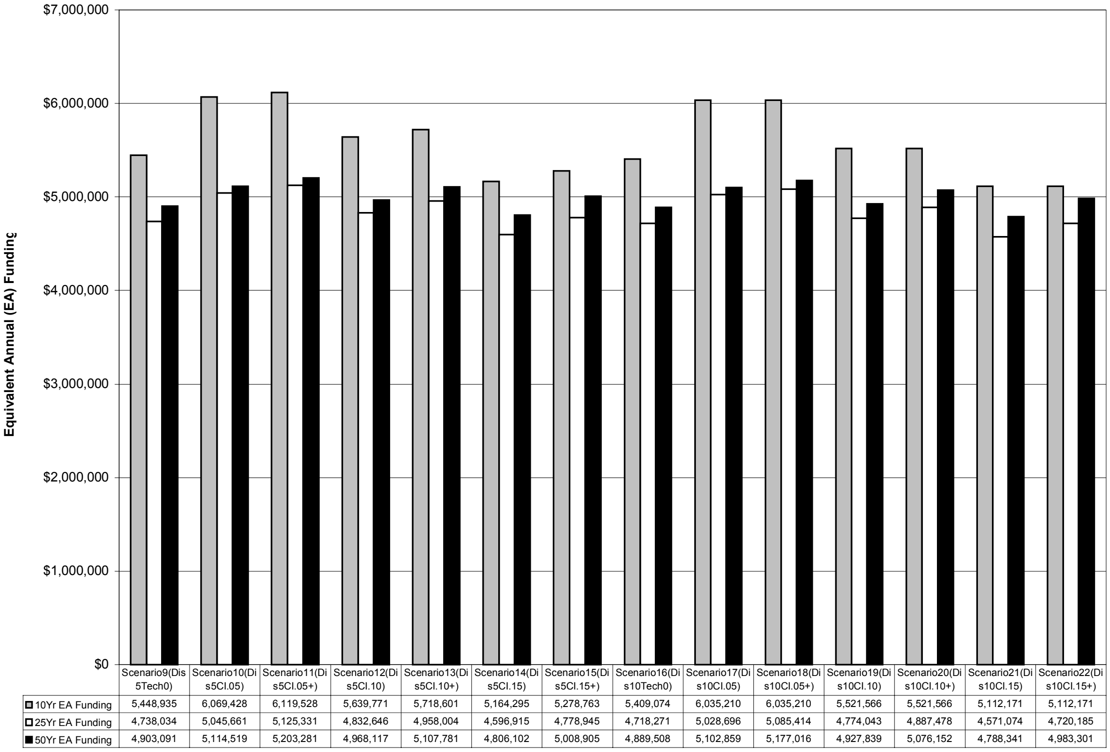


Figure 5-16 Forecasted Funding of Technical Backlog for Scenarios that Maintain Targeted Condition (Fort Stewart)

Figure 5-17 summarizes equivalent annual funding for the discretionary investment scenarios. Scenario 12 requires the most funding and Scenario 22 the least. The difference in equivalent annual funding between these best and worst condition scenarios is just over $1 million over a 10-year horizon, and the margin decreases to roughly $400,000 over the longer funding equivalent horizons. Relative to Portfolio I the funding disparity is less evident in Portfolio II, since the latter has a much better initial condition posture and requires less funding to improve.



	Scenario9(Dis5Tech0)	Scenario10(Dis5Cl.05)	Scenario11(Dis5Cl.05+)	Scenario12(Dis5Cl.10)	Scenario13(Dis5Cl.10+)	Scenario14(Dis5Cl.15)	Scenario15(Dis5Cl.15+)	Scenario16(Dis10Tech0)	Scenario17(Dis10Cl.05)	Scenario18(Dis10Cl.05+)	Scenario19(Dis10Cl.10)	Scenario20(Dis10Cl.10+)	Scenario21(Dis10Cl.15)	Scenario22(Dis10Cl.15+)
▨ 10Yr EA Funding	5,448,935	6,069,428	6,119,528	5,639,771	5,718,601	5,164,295	5,278,763	5,409,074	6,035,210	6,035,210	5,521,566	5,521,566	5,112,171	5,112,171
☐ 25Yr EA Funding	4,738,034	5,045,661	5,125,331	4,832,646	4,958,004	4,596,915	4,778,945	4,718,271	5,028,696	5,085,414	4,774,043	4,887,478	4,571,074	4,720,185
■ 50Yr EA Funding	4,903,091	5,114,519	5,203,281	4,968,117	5,107,781	4,806,102	5,008,905	4,889,508	5,102,859	5,177,016	4,927,839	5,076,152	4,788,341	4,983,301

Figure 5-17 Equivalent Annual Funding for Discretionary Funding Scenarios (Fort Stewart)

5.6 Investigation of Scenarios with New Assets

5.6.1 DEFINING SCENARIOS WITH NEW ASSETS

Adding new assets or replacing existing assets influences the overall condition of the facility portfolio. The intent of this section is to explore the extent to which *development* impacts capital and condition, rather than to address whether investment in new assets should be undertaken. That is, the analysis conducted is not a detailed economic study supporting the decision of whether to invest or not. Replacement assets affect portfolio condition, as the backlog associated with replaced facilities is eliminated in the year the replacement facility is commissioned. Furthermore, new assets influence future funding needs with the addition of *operations* and *sustainment* requirements. The extent to which a facility portfolio is affected by *development* depends on the type of facility added and the types and number of facilities replaced. In Portfolio I (Fort Belvoir), a new hospital replaces the existing hospital and two outlying clinics. In Portfolio II (Fort Stewart), a new clinic replaces three existing health clinics.

Table 5-6 summarizes the scenarios developed for investigating the impact of adding new facilities to both portfolios. The scenarios explore minimum funding and maximum condition based on the current *development* program, and a 5-year delayed program. The first, Scenario 23, introduces replacement facilities to the portfolio as they are currently programmed. Existing facilities are minimally funded. The second, Scenario 24, seeks to maximize the condition of the assets that remain when the new facilities are commissioned. In this case, the new assets are funded and built as currently programmed, while the technical backlog of existing facilities is level funded and retired in the same year the new assets are occupied. Scenario 25 is the same as Scenario 23, except construction of new facilities is delayed five years. The final scenario (Scenario 26) imposes a 5-year delay on Scenario 24.

Scenario	No.	Description
Minimum Funding + New Assets	23	Operations and Sustainment is funded to match requirements; All backlog is unfunded; New & Replacement assets are funded as programmed
Maximum Condition + New Assets	24	Operations and Sustainment are funded to match requirements; Technical backlog for assets not to be replaced is eliminated over periods up to replacement; Improvement and Development for existing assets is unfunded; New & Replacement assets are funded as programmed
Minimum Funding + New Assets (Delayed 5 years)	25	Operations and Sustainment is funded to match requirements; All backlog is unfunded; New & Replacement assets are funded 5 years from current program
Maximum Condition + New Assets (Delayed 5 years)	26	Operations and Sustainment are funded to match requirements; Technical backlog for assets not to be replaced is eliminated over periods up to replacement; Improvement and Development for existing assets is unfunded; New & Replacement assets are funded 5 years from current program

Table 5-6 Descriptions of Scenarios with New Assets

5.6.2 RESULTS AND ANALYSIS OF SCENARIOS WITH NEW ASSETS: PORTFOLIO I

Figure 5-18 displays the projected conditions for scenarios with new assets. In Portfolio I, *development* results in a much improved condition state, since the majority of backlog, which is associated with the existing hospital, is eliminated by the replacement hospital. Scenario 24 and Scenario 26 maximize the condition posture, given the programmed *development*, by eliminating the backlog associated with other facilities. Scenario 24 eliminates total backlog by period 6, when the replacement hospital is completed. Scenario 26 achieves the same results by period 10. Although Scenario 23 and Scenario 25 minimally fund existing assets, the replacement facility results in a drastic improvement in portfolio condition. Scenario 23 achieves a condition index value of 0.04 by period 6, while Scenario 25 does so by period 10. However, both scenarios permit the facilities remaining after *development* to deteriorate further, resulting in a portfolio condition index of nearly 0.09 by the end of 50 years.

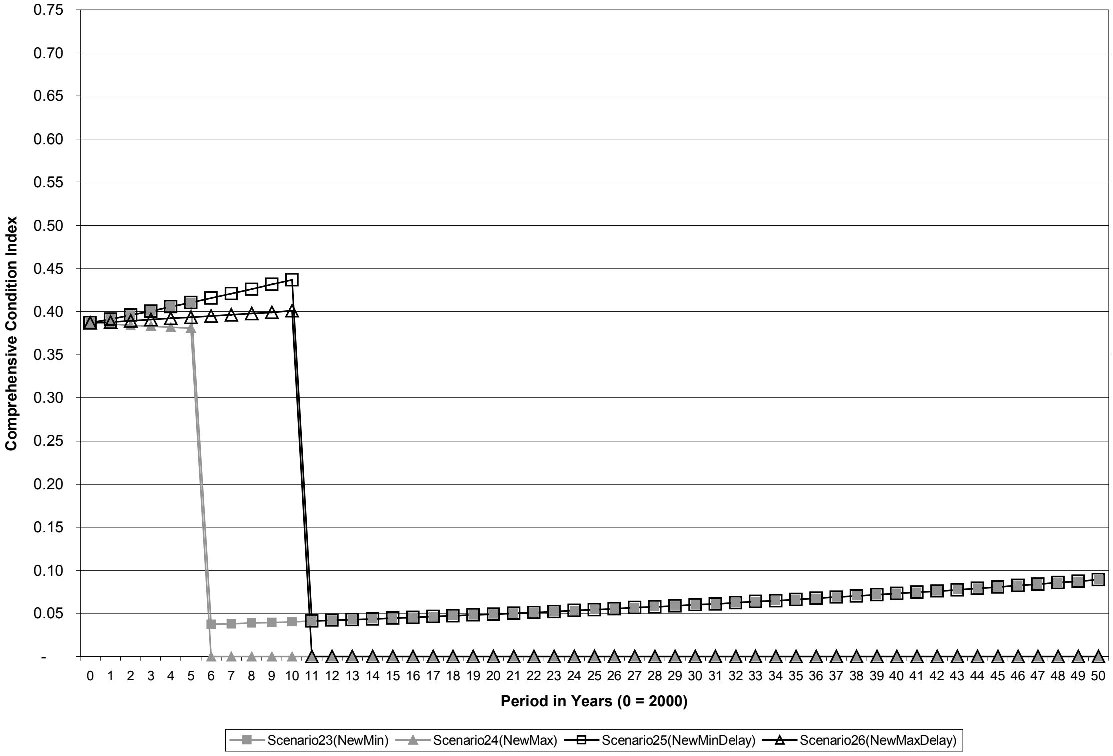
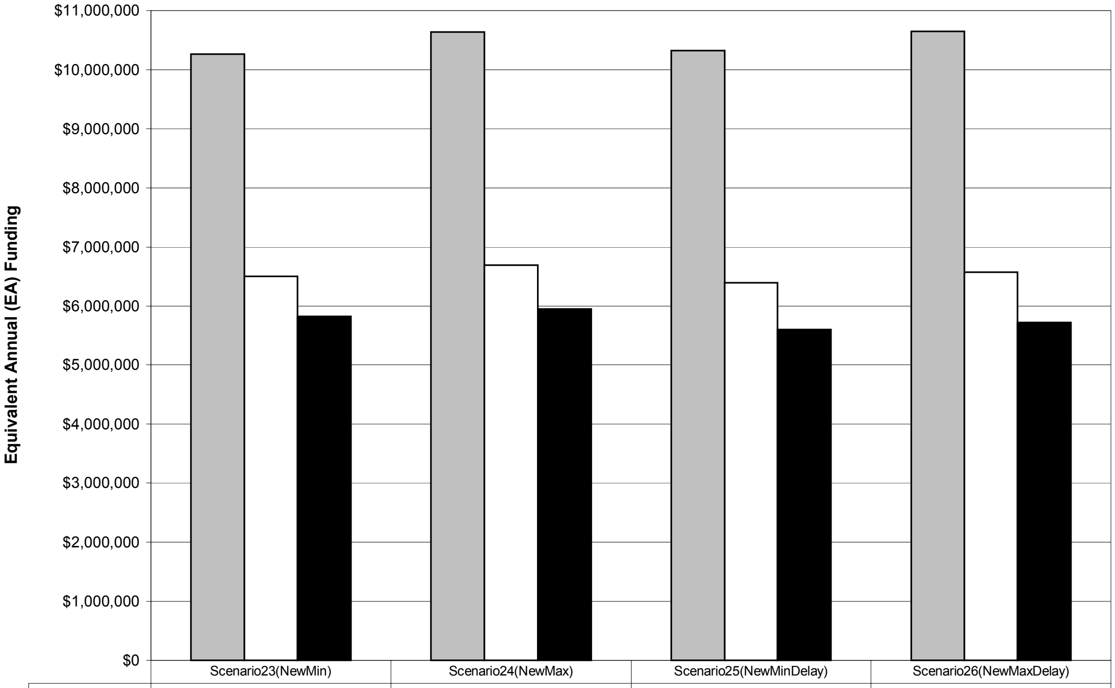


Figure 5-18 Projected Comprehensive Condition Indices for Scenarios with New Assets (Fort Belvoir)

As shown in Figure 5-19, these scenarios are nearly identical in terms of equivalent annual funding; however, they vary greatly over different equivalent funding horizons. Over a 10-year equivalent horizon, the difference in funding between the highest expense scenario (Scenario 26) and the lowest expense scenario (Scenario 23) is a mere $380,000, or less than 4%. Over longer time spans, the high and low equivalent annual funding scenarios switch to Scenario 24 and Scenario 25, respectively. This change is attributable to significant renewal needs for the hospital occurring in year 10. Since Scenario 25 and Scenario 26 are delayed five years, construction of the new hospital is completed in period 11, rather than period 6. Consequently, the renewal spike in year 10 is funded and over $10 million added to the delayed *development* scenarios.

The high-low funding disparity is less than 5% over a 25-year equivalent perspective and less than 7% over 50 years, as the absolute difference remains nearly the same.



	Scenario23(NewMin)	Scenario24(NewMax)	Scenario25(NewMinDelay)	Scenario26(NewMaxDelay)
▨ 10Yr EA Funding	$10,268,447	$10,634,378	$10,324,919	$10,653,538
☐ 25Yr EA Funding	$6,505,449	$6,686,870	$6,393,422	$6,569,989
■ 50Yr EA Funding	$5,824,043	$5,948,731	$5,599,066	$5,720,418

Figure 5-19 Equivalent Annual Funding for Scenarios with New Assets (Fort Belvoir)

5.6.3 RESULTS AND ANALYSIS OF SCENARIOS WITH NEW ASSETS: PORTFOLIO II

The impact of *development* is less dramatic than in Portfolio I, where the existing hospital accounting for the bulk of backlog is replaced. The Fort Stewart portfolio adds a new clinic that replaces three existing clinic facilities, which accounts for a small percentage of total backlog. Figure 5-20 exhibits the projected conditions for Portfolio II. Scenario 24 and Scenario 26 are nearly the same as the maximum-condition scenarios (Scenarios 3 and 4) in terms of how they influence condition over time. Each scenario eliminates backlog; however, Scenario 24 and Scenario 26 rely on new assets as part of the solution. Conversely, Scenario 23 and Scenario 25 are similar to the minimum-funding scenario (Scenario 1) with a marginal offset in the condition curve over time. A quick review of Figure 5-6 reveals the similitude. Scenario 23 and Scenario 25 differ only in the timing of improvement and then follow the same condition posture going forward.

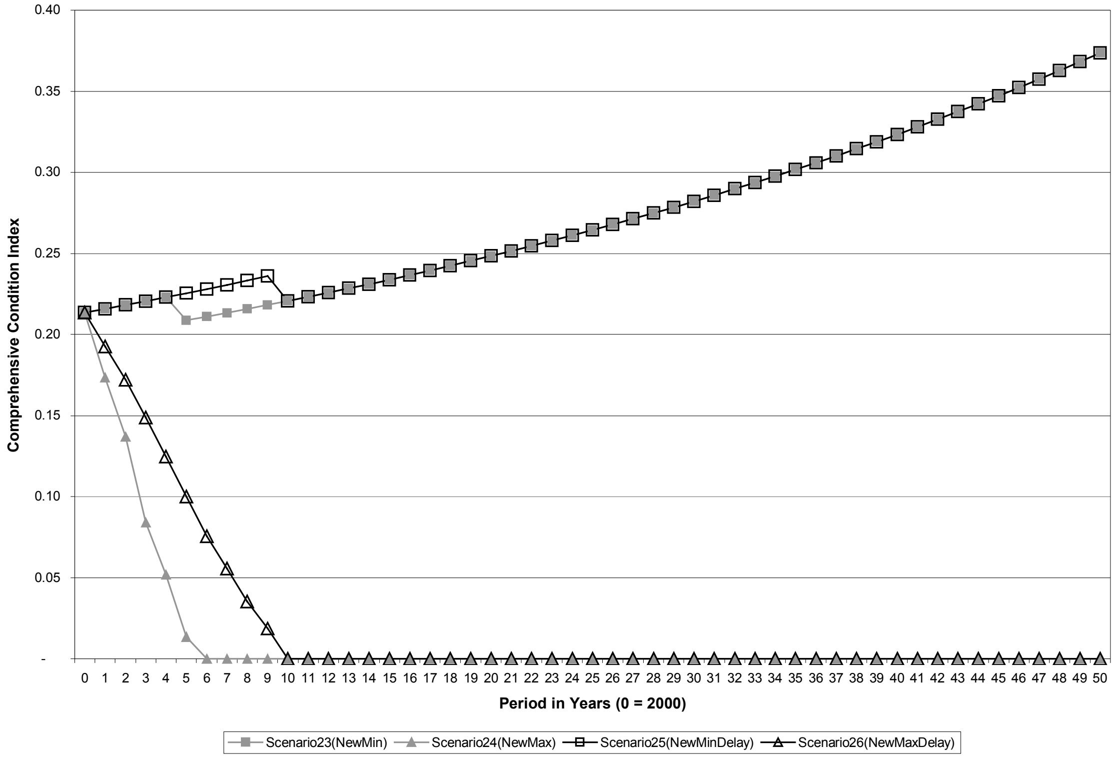
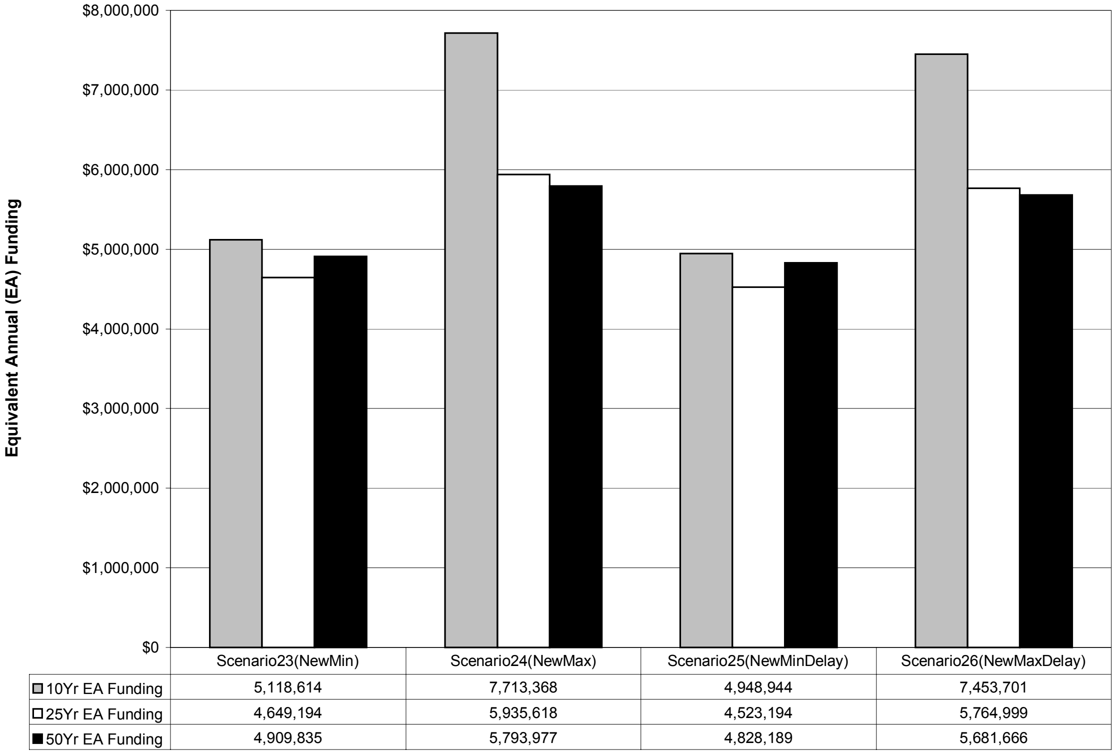


Figure 5-20 Projected Comprehensive Condition Indices for Scenarios with New Assets (Fort Stewart)

The disparity in forecasted condition is also reflected in equivalent annual funding shown in Figure 5-21. The scenarios that improve condition the most require roughly $7.5 million per year over a 10-year horizon, while those that mirror the minimum-funding scenario are close to $5 million annually. Over the 25-year and 50-year spans for calculating equivalents, the funding gap decreases to approximately $5.8 million and $4.8 million annually. Relative to the boundary scenarios results (refer to Figure 5-7), the scenarios with new assets cost roughly $400,000 more per year to achieve very similar condition. An additional $884,000 over 10 years and $247,000 over 50 years supports the replacement health clinic; however, Scenario 23 and Scenario 25 do not effectively manage condition over the long run.



	Scenario23(NewMin)	Scenario24(NewMax)	Scenario25(NewMinDelay)	Scenario26(NewMaxDelay)
▨ 10Yr EA Funding	5,118,614	7,713,368	4,948,944	7,453,701
☐ 25Yr EA Funding	4,649,194	5,935,618	4,523,194	5,764,999
■ 50Yr EA Funding	4,909,835	5,793,977	4,828,189	5,681,666

Figure 5-21 Equivalent Annual Funding for Scenarios with New Assets (Fort Stewart)

5.7 Analysis of the Collection of Scenarios

5.7.1 INTRODUCTION TO ANALYZING THE SCENARIO COLLECTION

The previous four sections have analyzed a range of solutions for balancing capital and condition, from the boundaries to a representative selection in between. Each section considered a manageable subset of the array of possibilities to illustrate the influence of condition, capital, pace of investment, and the mix of assets. Moreover, each section presented and analyzed condition separately from funding. In this section, the array of solutions are combined and examined as a portfolio of investment strategies. These strategies are analyzed in view of both condition and capital, so that tradeoffs become more apparent.

Combining, presenting, and analyzing multiple scenarios (26 scenarios for each portfolio in this analysis) necessitates some manipulations to the period-by-period condition index. As discussed in chapter 2, the condition index is converted to an equivalent annual ratio by calculating equivalent annual backlog and equivalent annual replacement value over various time horizons. In effect, the equivalent annual condition index provides a single value representing several periods of condition. Scenarios may then be compared in terms of how effectively each manages condition over different time horizons, as a supplement to comparing them period-by-period. The equivalent annual condition index also accounts for the time value money. The equivalent annual backlog and facility replacement value is discounted so that future values are weighted less, the degree to which is determined by the selected discount rate. Lower discount rates place more emphasis on future values, while higher rates emphasize the present. Hence, the economic assumptions pertaining to a given organization are also reflected in the equivalent annual condition index.

5.7.2 ANALYSIS OF SCENARIO COLLECTION: PORTFOLIO I

Figure 5-22 displays all scenarios for Portfolio I in terms of the equivalent annual condition index, which, as before, is calculated over a 10, 25, and 50-year time span. The scenarios are sorted from best to worst condition based on the 25-year horizon. The 10 and 50-year horizons are also displayed to illustrate differences in results over shorter and

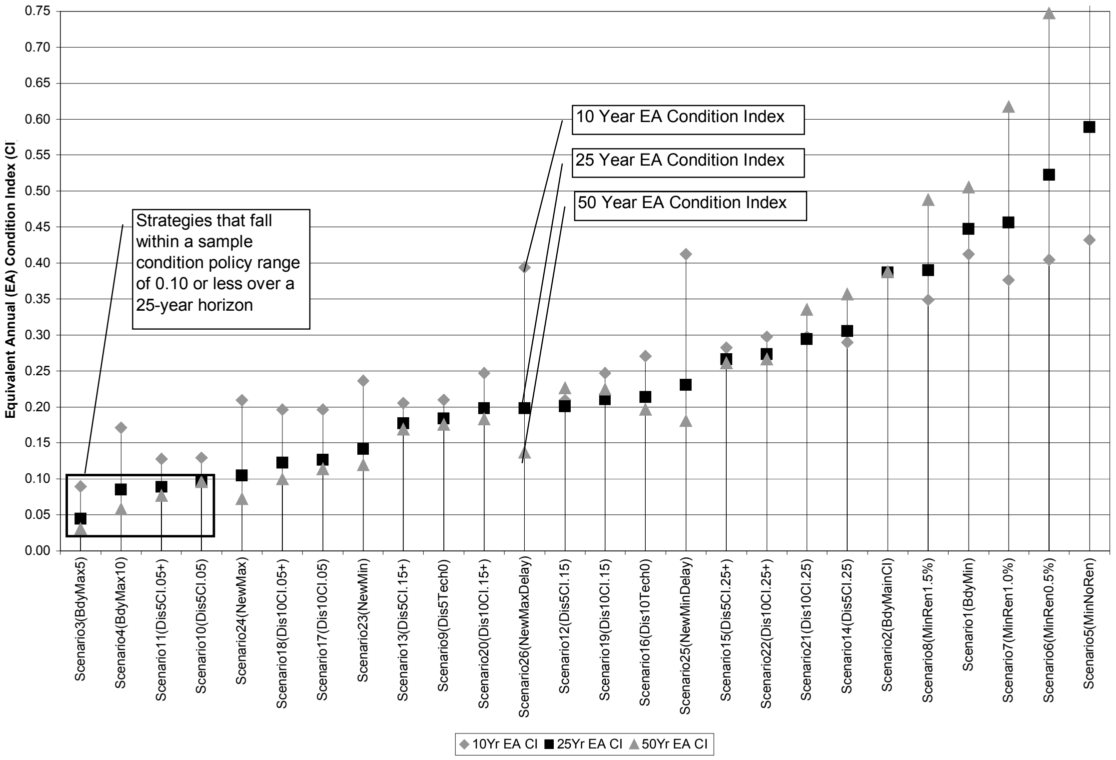


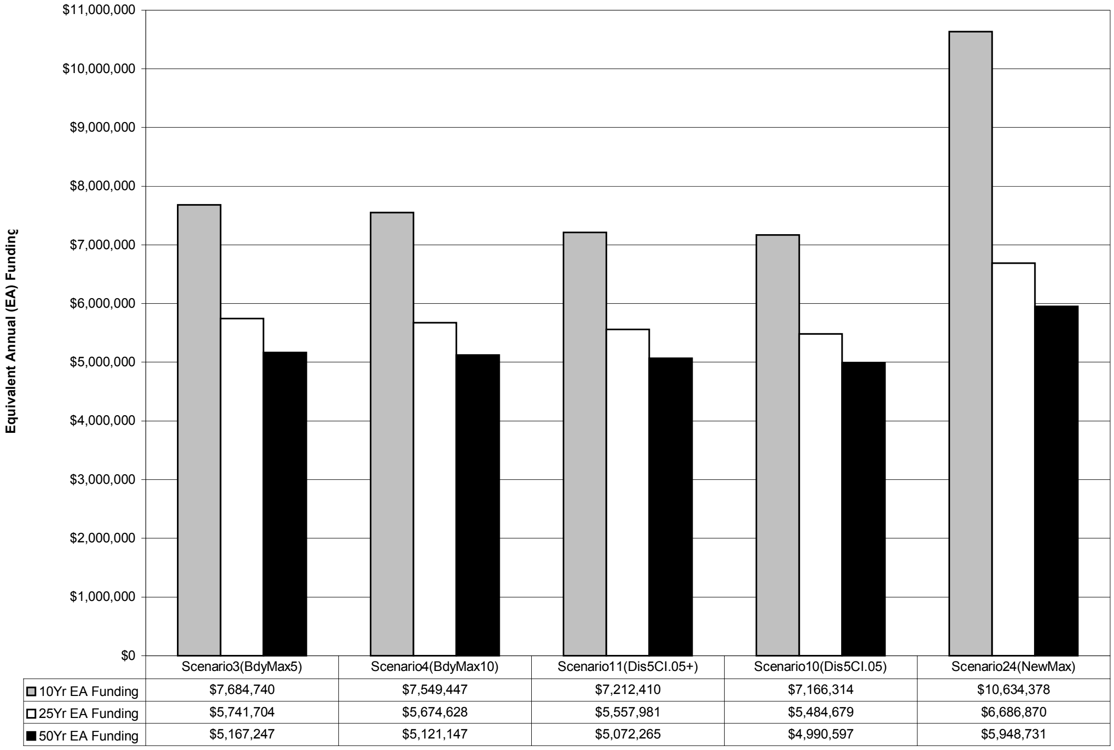
Figure 5-22 Collection of Scenarios Arrayed by Equivalent Annual Condition Index (Fort Belvoir)

longer time horizons. The boundary scenarios that maximize facility condition (Scenarios 3 and 4) are arrayed to the left, while those that minimize condition (Scenarios 1, 5, 6, 7, and 8) are toward the right. Scenarios that achieve various target condition levels, mainly those associated with discretionary funding levels, comprise the middle portion of the graph. Scenarios that introduce new assets to the mix of existing facilities (Scenarios 23, 24, 25, and 26) are interspersed among the discretionary funding scenarios.

Arraying the scenarios collectively emphasizes the significance of the facilities decision-maker's time perspective when evaluating investment strategies. It is evident from Figure 5-22 that the time horizon for considering facility condition influences the scenarios' ranking, which fluctuates somewhat over the three different time spans. The most notable examples of this fluctuation involve Scenarios 25 and 26, where both appear among the worst condition scenarios over the short term, but shift toward the better condition scenarios over the long term. Both scenarios replace existing assets with a new hospital facility and both delay the currently programmed replacement by 5 years. This result is consistent with the condition profiles in Figure 5-18, where the baseline index increases (condition deteriorates) over the first 10 years before the replacement facility is completed. Hence, for both scenarios the short-term perspective captures only the periods of deteriorating condition, while the long-term horizon includes the improved condition periods. There are other examples of scenarios changing order; however, in general, the scenarios rank consistently over the different time horizons. That is, scenarios resulting in poor conditions group to the right in the figure, while those resulting in better conditions array to the left.

In addition, condition variation across scenarios is more pronounced over longer time spans. Over a 50-year horizon, the worst condition result exceeds 0.75, while the best result is 0.03. In contrast, condition results over a 10-year horizon vary between 0.43 and 0.09. The long-term perspective amplifies condition results by considering many more periods of facility backlog. This is particularly evident in the scenarios that result in worse conditions, as larger levels of backlog increase more severely over longer periods. The scenarios arrayed to right of the figure demonstrate this effect.

Arraying the collection of strategies by condition also permits the decision-maker to target an "acceptable" range for a given time horizon and examine the funding implications for those falling within this range. As an example, a condition policy of 0.10 or less over a 25-year horizon may be established. From Figure 5-22, it is readily evident that Scenarios 3, 10, 17, 18, and 24 fall within the bounds of this policy. Each may then be examined in terms of funding, pace, and timing of investment. Equivalent annual funding for the five scenarios is shown in Figure 5-23 as a starting point; however, each strategy may consider funding period-by-period in terms of the various investment classes. From Figure 5-23, it is evident that each scenario requires significant capital outlay over the short-term, and each requires relatively similar magnitudes of funding over all time horizons with the exception of Scenario 24. The decision-maker at this point effectively has a guide for further consideration.



	Scenario3(BdyMax5)	Scenario4(BdyMax10)	Scenario11(Dis5CI.05+)	Scenario10(Dis5CI.05)	Scenario24(NewMax)
▨ 10Yr EA Funding	$7,684,740	$7,549,447	$7,212,410	$7,166,314	$10,634,378
☐ 25Yr EA Funding	$5,741,704	$5,674,628	$5,557,981	$5,484,679	$6,686,870
■ 50Yr EA Funding	$5,167,247	$5,121,147	$5,072,265	$4,990,597	$5,948,731

Figure 5-23 Range of Scenarios that Attain Sample Condition Policy (Fort Belvoir)

Figure 5-24 further emphasizes the importance the facilities decision maker's time perspective. This figure portrays the scenario collection in terms of equivalent annual funding over the three different time horizons; scenarios are sorted in descending order of funding over the 25-year horizon. The variation across all scenarios from most to least funding is less for the longer time horizons ($6 million to $2 million) and greater for the short-term perspective ($10.6 million to $2 million). Funding variation is also evident within particular scenarios. For example, funding for Scenario 24 fluctuates from $10.6 million for the 10-year horizon to $6 million for the 50-year horizon. The wide funding variance associated with the scenarios toward the left of the figure suggests that improving facility condition requires significant investment at the outset with sustained levels of funding over the long run.

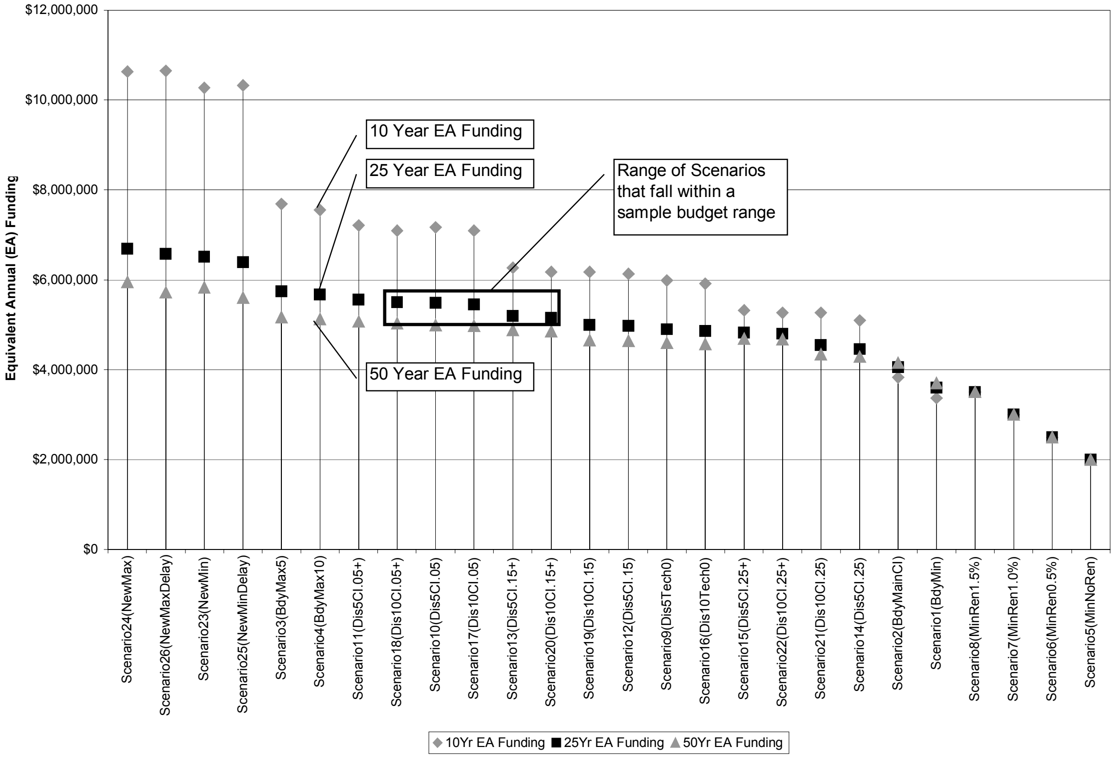


Figure 5-24 Collection of Scenarios Arrayed by Equivalent Annual Funding (Fort Belvoir)

Annual funding for each scenario arrays in distinctive bands over the short-term horizon. For example, scenarios with new assets (Scenarios 23, 24, 25, and 26) are clearly distinguishable in the annual funding range from $10.6 to $10.2 million. These annual funding bands are further delineated by the range of target condition values. For example, the maximum condition scenarios (Scenarios 3 and 4) and the scenarios that target a condition index of 0.05 (Scenarios 10, 11, 17, and 18) are in the band of funding from $7.7 million to $7.1 million. The next funding band is from $6.3 million to $5.9

million, and it includes scenarios that target a condition index of 0.15 (Scenarios 12, 13, 19, and 20) and those that fund only technical backlog (Scenarios 9 and 16). The final band is comprised of scenarios that target a condition index of 0.25 (Scenarios 15, 16, 21, and 22), and it ranges from $5.3 million to $5.1 million.

Figure 5-24 enables the facilities decision-maker to view multiple scenarios from an affordability standpoint. The sample grouping in the figure illustrates those scenarios falling within a hypothetical budget range of $5million to $5.5 million over a 25-year horizon. Both the horizon and budget range could vary to produce other groupings of scenarios. Scenarios that fall within the available budget range can then be viewed on a period-by-period basis to evaluate how effectively each manages condition and aligns with other strategic concerns, such as, pace of investment, replacement cycle, and holding period. As an example, the selected funding range in Figure 5-24 bounds Scenarios 10, 13, 17, 18, and 20. These scenarios are displayed in terms of condition over time in Figure 5-25. The decision-maker can now effectively compare the various investment strategies that fall within budget. Each strategy effectively manages backlog, so the replacement threshold is not reached. Furthermore, each strategy is bounded by

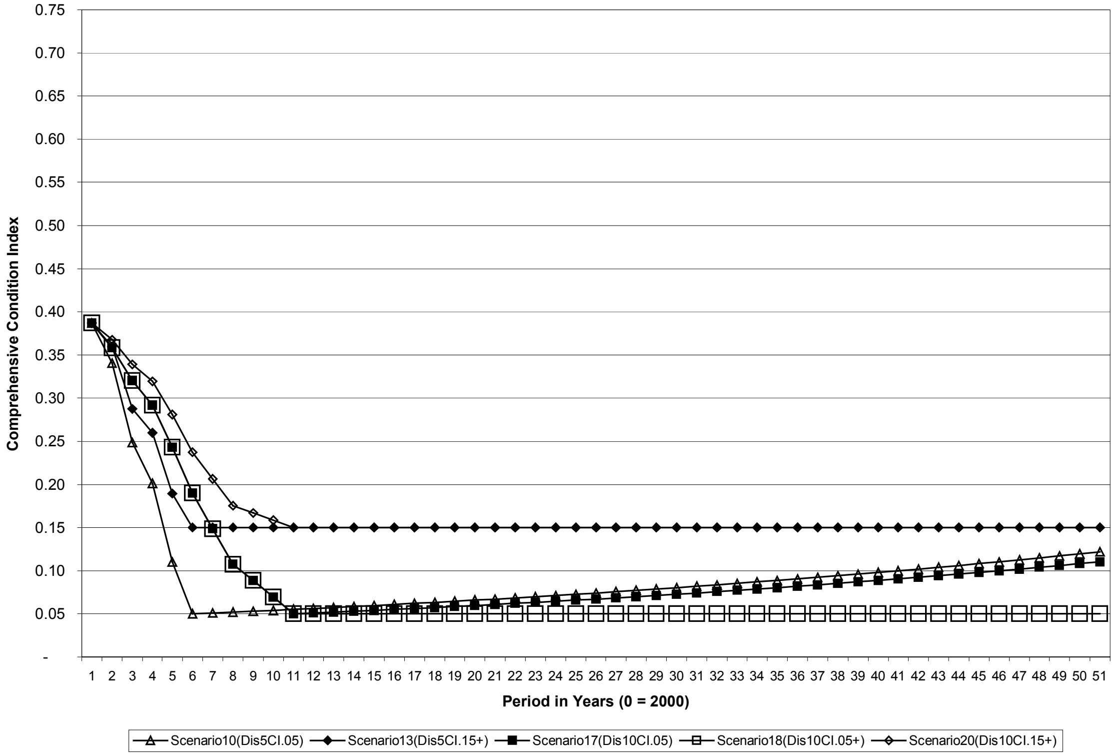


Figure 5-25 Range of Scenarios within Sample Budget Range (Fort Belvoir)

condition states of 0.15 and 0.05. The decision-maker may now consider the significance of investment pace, final condition state, and the extent to which the final state is maintained over time.

5.7.3 ANALYSIS OF SCENARIO COLLECTION: PORTFOLIO II

The collection of scenarios for Fort Stewart is shown in Figure 5-26. As before, scenarios are displayed over the three different time horizons and are sorted in ascending order by the equivalent annual condition index. The best condition scenarios align to the left of the figure, while those with the worst condition results dominate the right of the figure. The maximum condition boundary scenarios (Scenarios 3 and 4) and the maximum condition scenarios with new assets (Scenarios 24 and 26) are at the left of the figure. The minimum funding scenarios (Scenarios 1, 5, 6, 7, and 8) and minimum funding scenarios with new assets (Scenarios 23 and 25) are at the right. The discretionary funding scenarios (Scenarios 9 through 22) comprise the middle portion of the graph.

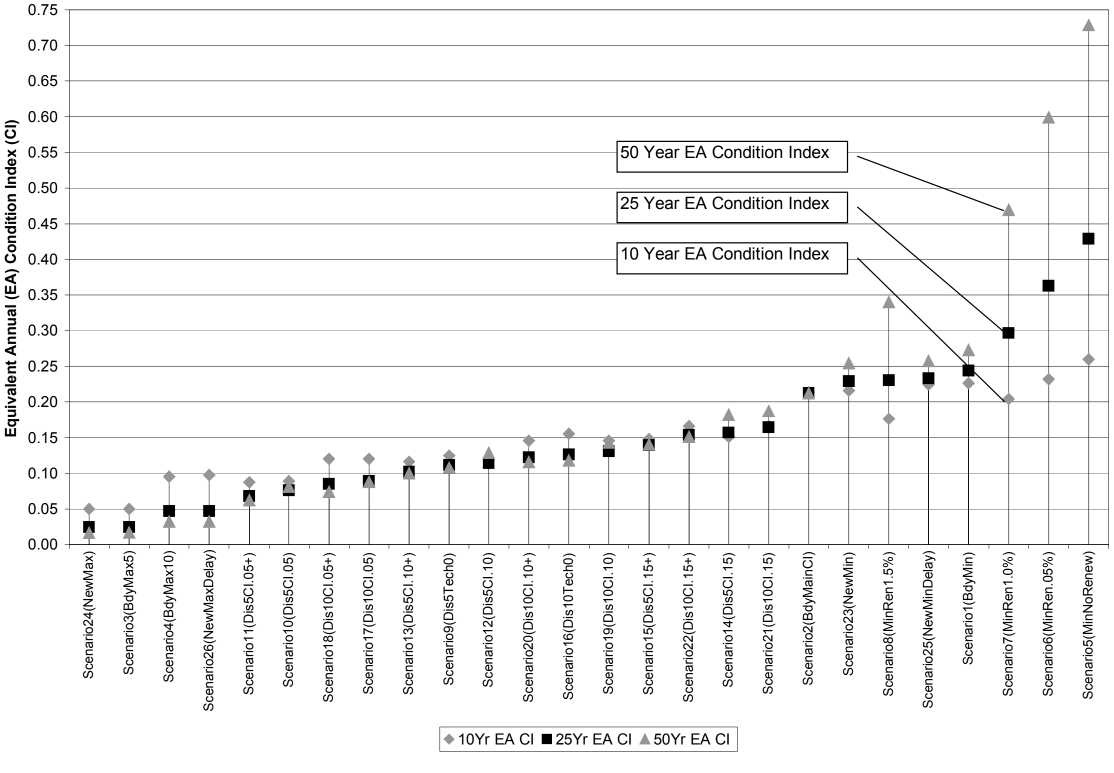


Figure 5-26 Collection of Scenarios Arrayed by Equivalent Annual Condition Index (Fort Stewart)

The variation of equivalent annual condition across scenarios is not nearly as pronounced as in Portfolio I. The variance is marginal with the exception of the minimum funding scenarios, where again accounting for several more periods of increasing backlog causes the equivalent annual condition index to rise sharply over longer time horizons. Consequently, the time perspective appears less significant for Portfolio II than for Portfolio I. The better baseline condition (i.e., lower levels of initial backlog) of Portfolio II primarily accounts for this difference. The reduction of low levels of backlog is much less pronounced relative to the more drastic variations associated with high levels of backlog. Furthermore, low levels of backlog increase over time less severely than high levels of backlog.

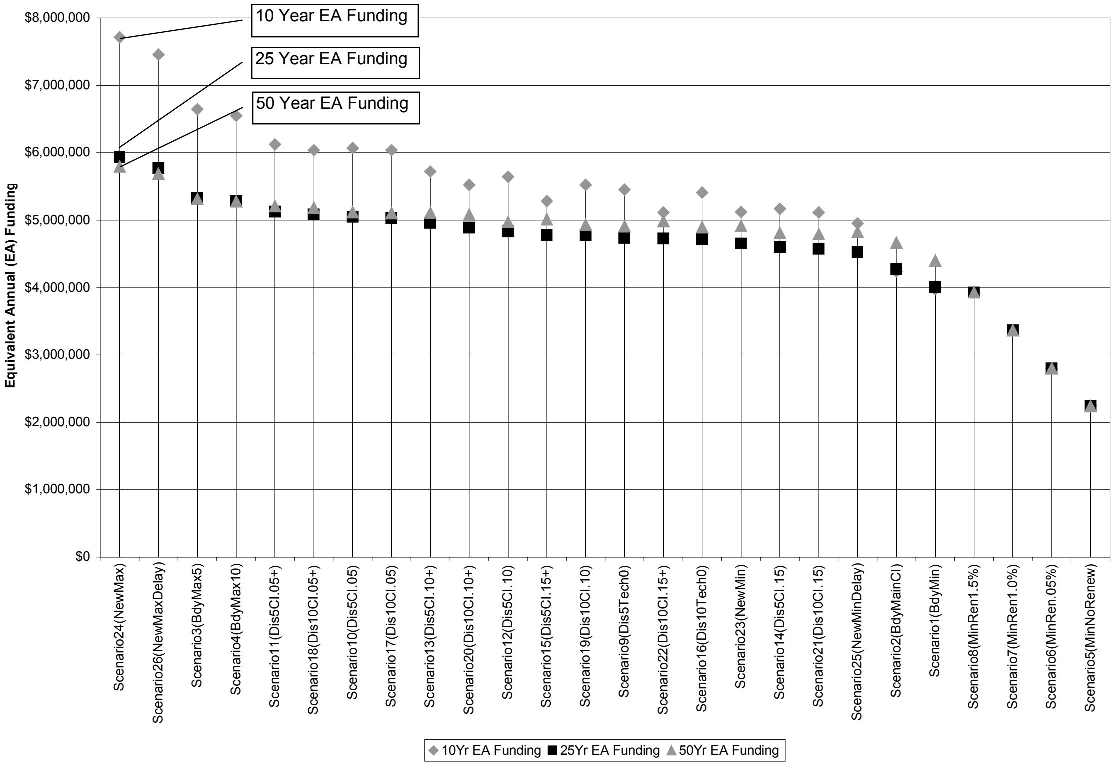


Figure 5-27 Collection of Scenarios Arrayed by Equivalent Annual Funding (Fort Stewart)

Figure 5-27 shows the scenario collection in terms of funding. Scenarios are arrayed in descending order based on funding requirements over a 25-year horizon. Relative to Portfolio I, funding variation is much less distinctive, as the scenarios with new assets and those that improve condition are less capital intensive for Portfolio II. Annual funding varies over the short-term from a high of $7.7 million to a low of $2.2

million. Over the longer terms, funding variation diminishes to a high of $5.9 million and a low of $2.2 million. Moreover, funding does not appear to cluster in distinguishable bands to the same extent as Portfolio I.

5.8 Sensitivity of Results to Cash Flow Variables

5.8.1 INTRODUCTION TO SENSITIVITY ANALYSIS

The techniques used for comparing investment strategies as a collection provides a useful approach for considering the sensitivity of cash flow variables. In this section, all 26 scenarios are regenerated for both portfolios using different values for two essential cash flow modeling variables. The collective results are then compared and the consequences of initial variable settings considered based on the equivalent annual condition index and equivalent annual funding. The comparison is made over the 25-year horizon, and the objective is to determine how consistent the different strategies rank over both horizons given changes to the initial modeling assumptions.

The most critical aspect of the current results is the method in which asset-based cash flows are modeled. The equivalent annual basis of comparison (which is dependent upon the discount rate) and the forecasted growth of backlog over time (which is dependent upon the systems deterioration rate) are the underlying variables that most influence how facilities condition and funding requirements are represented. Accordingly, the discount rate and the systems deterioration rate are the variables considered for sensitivity. The other cash flow variables, mainly the inflation variables and replacement threshold, do not influence the comparative modeling results. The replacement threshold is simply a decision point and has no effect on cash flows. While inflation impacts the period-by-period cash flows, its effect when discounting is negligible (refer to section 4.4.1).

Sensitivity is tested at the extremes of these two variables. Table 5-6 summarizes the values applied in generating new cash flow scenarios. The baseline alternative represents the current results presented in the preceding sections. Section 4.4.2 in the previous chapter discusses the values used in producing the baseline cash flows. The sensitivity alternative titled “DiscRate8%” uses a real discount rate of 8%, all else equal. Relative to historical annual yields of the 30-year U.S. Treasury bond net of inflation, 8%

represents a relative high. The sensitivity alternative titled “DetRate10%” uses a systems deterioration rate of 10%, all else equal. This value was the high end of a range of reasonable values considered by Rush (1991) when modeling aggregate backlog.

Sensitivity Alternative	Discount Rate (Real Rate)	Systems Deterioration Rate
Baseline	3.2% per annum	2.0% per annum
DiscRat8%	8.0% per annum	2.0% per annum
DetRat10%	3.2% per annum	10% per annum

Table 5-7 Sensitivity Analysis Alternatives

5.8.2 SENSITIVITY RESULTS: PORTFOLIO I

The sensitivity results for the Fort Belvoir portfolio are presented in Figure 5-28, which shows condition results, and Figure 5-29, which displays funding results. Figure 5-28 arrays the scenarios in ascending order based on the condition results of the baseline alternative, while Figure 5-29 displays scenarios in descending order of funding.

It is evident in Figure 5-28 that condition results vary marginally for those scenarios that reduce backlog and improve condition. The variance is more pronounced

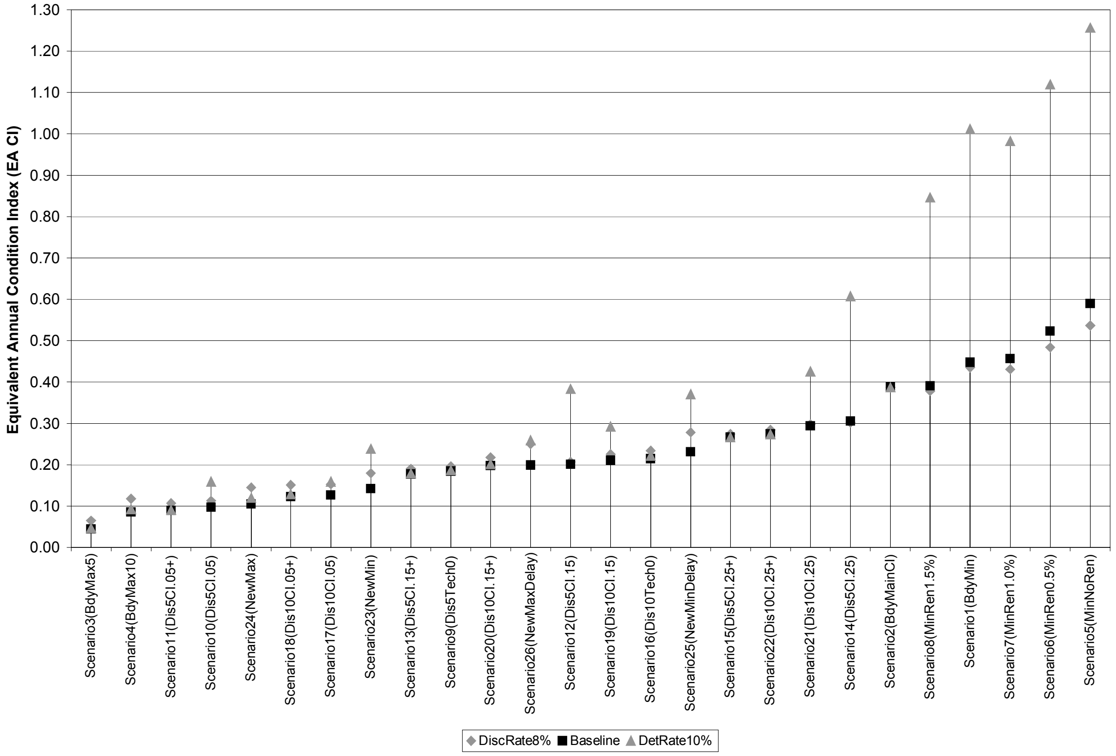


Figure 5-28 Results of Sensitivity Analysis on Condition over 25-Year Horizon (Fort Belvoir)

(up to 114%) for the minimum funding scenarios that are arrayed to the right of the figure. Despite these variances, the overall rank of the scenarios is unchanged with few exceptions. Thus, the decision to pursue an investment strategy based on condition is unaffected by the changes to the discount rate or systems deterioration rate. The higher systems deterioration rate appears to have the more significant effect on the variation of condition values, while the effect of the discount rate is negligible.

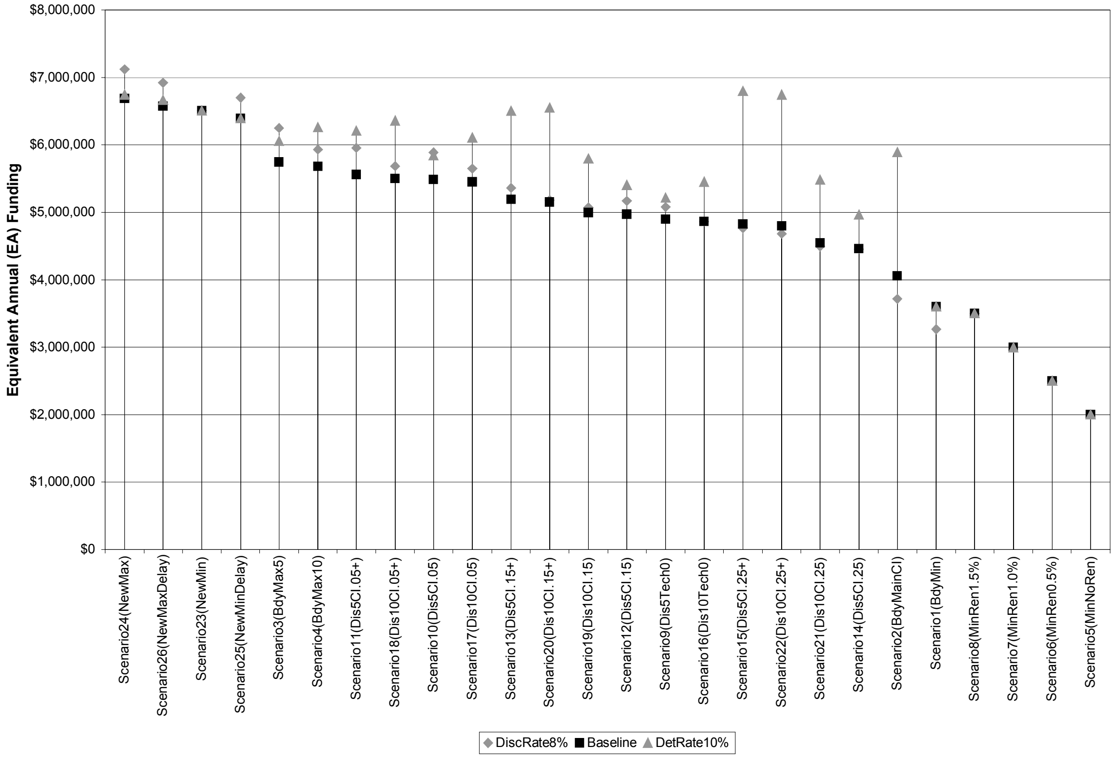


Figure 5-29 Results of Sensitivity Analysis on Funding over 25-Year Horizon (Fort Belvoir)

The results in Figure 5-29 illustrate the sensitivity of equivalent annual funding. Clearly scenarios based on the higher deterioration rate have some impact on the magnitude of requisite funding, particularly for those scenarios that maintain high levels of backlog. For instance, Scenarios 13 and 20 maintain a condition level of 0.15 and the requisite funding for each increase by 25%. In addition, Scenarios 15 and 22 maintain a condition level of 0.25. The requisite funding for these two scenarios increases by 42%. The order of strategies in funding terms appears to change for those comprising the middle portion of the graph, mainly those that carry high levels of backlog. The change in the discount rate has a nominal effect on funding levels and does not appear to significantly change the order of scenarios.

5.8.3 SENSITIVITY RESULTS: PORTFOLIO II

The sensitivity results for Fort Stewart are shown in Figure 5-30 and Figure 5-31. The former displays scenarios in ascending order of condition, while the latter arrays scenarios in descending order of funding. As in the case of the Fort Belvoir portfolio, the order of scenarios based on condition results for Fort Stewart vary only marginally for the higher deterioration and discount rates. The higher deterioration rate affects mainly those scenarios that do not control and maintain condition over time. For instance, the minimum funding scenarios to the right of Figure 5-30 increases by up to 100%. In addition, Scenarios 12, 14, 19, and 21 (all of which target higher condition index values and do not maintain these values once attained) result in worse condition states due to the higher deterioration rate.

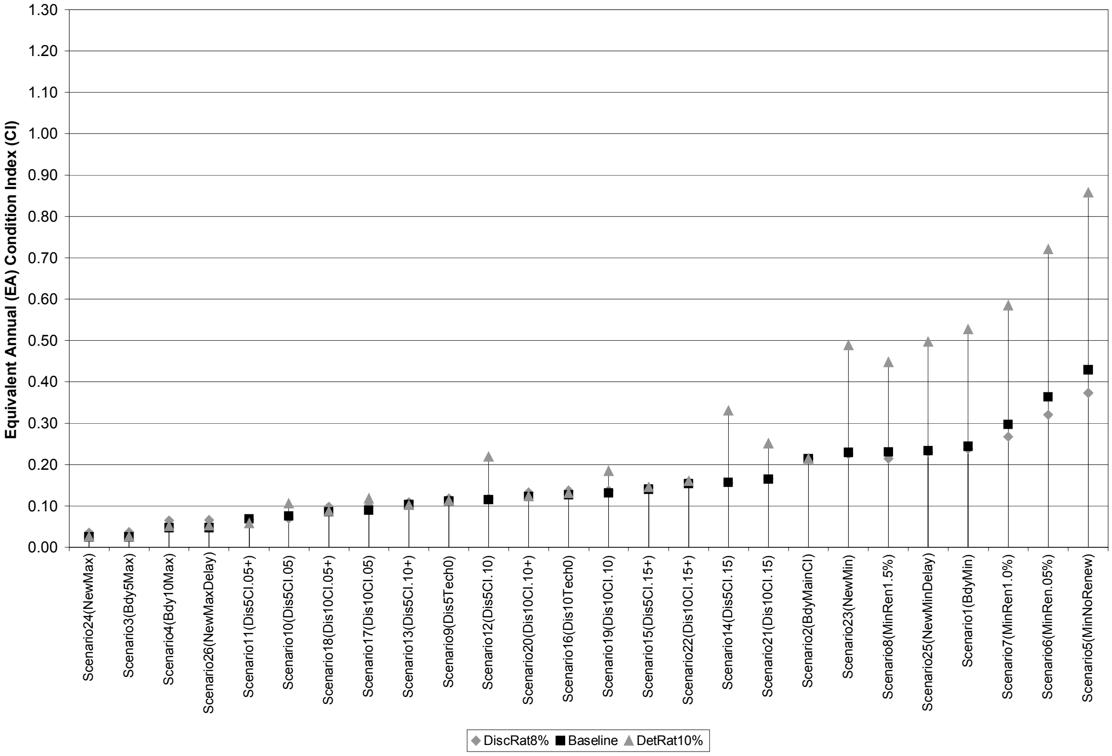


Figure 5-30 Results of Sensitivity Analysis on Condition over 25-Year Horizon (Fort Stewart)

Figure 5-31 displays the sensitivity of equivalent annual funding levels for Fort Stewart. While the higher discount rate has a minimal effect on requisite funding, the higher deterioration rate results in increased levels of funding for those scenarios that achieve and maintain a target condition value. For example, Scenarios 13 and 20, which improve and maintain a condition index of 0.10, and Scenarios 15 and 22, which improve and maintain a condition index of 0.15, require higher levels of funding to counter the effects of an increased deterioration rate. That is, greater levels of backlog growing at higher rates necessitate more funding. Scenarios that maintain high levels of backlog comprise the middle portion of the graph and thus shift toward the more capital-intensive scenarios to the left. Interestingly over the 25-year horizon, it is more cost effective to eliminate backlog completely over the initial 5 to 10 years than it is to sustain backlog over longer periods of time. The maximum condition scenarios (Scenarios 3 and 4) require some $5.5 million, while scenarios that achieve and maintain a targeted condition index necessitate from $5.6 million (Scenarios 11 and 18) to $6 million (Scenarios 15 and 22).

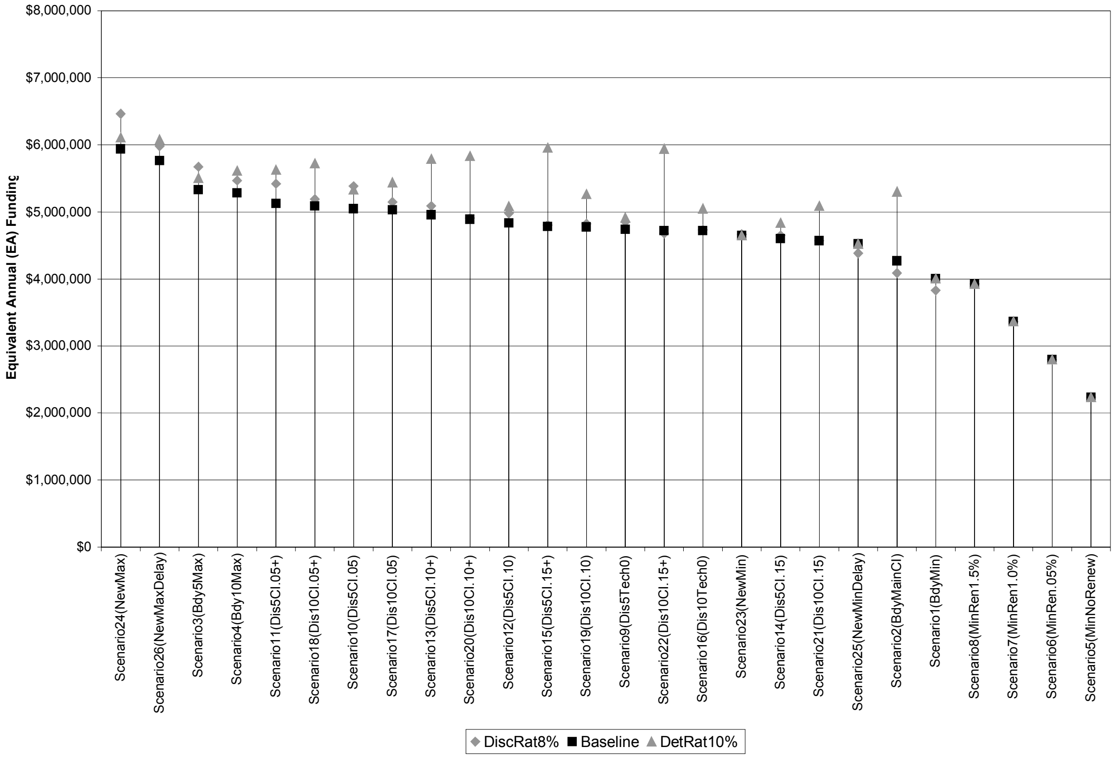


Figure 5-31 Results of Sensitivity Analysis on Funding over 25-Year Horizon (Fort Stewart)

Chapter 6 Summary & Evaluation of Tool

6.1 Summary

6.1.1 SUMMARY OF APPLICATION

The results and analysis demonstrate how condition and capital can be balanced within various degrees of constraint to effectively establish a suitable facilities investment strategy. The prototype decision support tool developed in this research was applied to two healthcare facility portfolios that are broadly representative of those in the U.S. Army. The tool readily permitted the exploration and comparison of 26 different investment scenarios; several more scenarios could easily be accommodated. In addition, the tool flexibly permitted consideration of a number of primary variables that are relevant in investigating alternative investment strategies. These variables include facility condition, funding, pace of investment, acquisitions and dispositions of assets, facility replacement cycles, and different time perspectives. The analysis treated facilities as a portfolio, so that condition and funding represented the aggregate. The tool is scalable and allows the decision-maker to focus on a single facility or a collection of facilities at any organizational level. Similarly, both condition and funding were viewed comprehensively, although both are also scalable. Condition can be treated comprehensively or it can be viewed in terms of its technical, functional, or capacity components. Likewise, funding can be considered in total or it can be delineated in terms of its constituent investment classes (i.e., *operations*, *sustainment*, *improvement*, or *development*).

The analytic approach was grounded in a real budget context that is representative of constraints facing institutional and public owners. This context provided the basis for developing and analyzing investment scenarios. Scenarios were defined in four investigative sections: 1) boundary scenarios, 2) minimum funding scenarios, 3) discretionary funding scenarios, and 4) scenarios with new assets. The first section explored the limits of the otherwise infinite solution set by minimizing funding and maximizing facilities condition. The second section reviewed the impact on facilities condition by applying gradations of minimum funding. Condition was thus dependent on different levels of funding. The facilities replacement cycle was also considered in this section. The third section treated condition independently in determining requisite levels of capital to achieve various target condition levels over a 5-year and 10-year pace. The final section explored the impact on condition and funding due to the acquisition and disposition of facilities.

The scenarios developed in these investigative sections were then combined and analyzed as a collection of investment solutions. The equivalent annual condition index facilitated this analysis by representing the condition profile over different time horizons as a single number. Scenarios were arrayed in order of condition and funding, so that more favorable investment strategies could be selected within ranges of each. The analysis included all scenarios developed throughout this chapter. However, it is clear that some scenarios are not viable strategies *a priori* and should be filtered before proceeding with the collective analysis. For example, scenarios that eliminate technical backlog exclusively or those that do not maintain condition levels once achieved may be excluded from the analysis. Analyzing the scenarios as a collection provided a convenient method for comparing the sensitivity of each investment strategy to changes in the discount rate and technical deterioration rate. Both variables were independently increased to “maximum” values and cash flows for each scenario regenerated for comparison with the baseline results.

6.1.2 SUMMARY OF OBSERVATIONS

A number of observations were made based on the results presented in each section. These observations primarily related to investment strategies and the variables employed in their development. They are predicated on the assumptions incorporated in the modeling tool and cash flow variables and are summarized as follows.

Baseline Portfolio Conditions. The two application portfolios were similar in size and scope of facilities; however, they differed greatly in terms of current assessed conditions. The baseline comprehensive condition index was 0.39 for Portfolio I (Fort Belvoir) and 0.21for Portfolio II (Fort Stewart). In other words, the estimated cost of existing backlog was 39% of the facilities replacement value for Portfolio I and 21% for Portfolio II.

Boundary Investment Strategies. The variation in annual equivalent funding between the minimum funding strategies and maximum condition strategies was notably different for the two application portfolios. The annual equivalent funding variation between the extreme strategies for Portfolio I (Fort Belvoir) was roughly $4.3 million (126%) over a 10-year horizon and $1.5 million (40%) over a 50-year horizon. Portfolio II (Fort Stewart), which had a much improved baseline condition, differed between the extreme strategies by $2.6 million (65%) over the short-term and $0.9 million (20%) over the long-term.

Minimum Funding Investment Strategies. For both portfolios, all minimum funding strategies resulted in condition indices that exceeded the replacement threshold in 48 years and less. Moreover, the replacement cycles estimated for each strategy in Portfolio I (Fort Belvoir) were 5 to 10 years less than Portfolio II (Fort Stewart). Minimum funding strategies were based on formula methods that resulted in level investment, but irregular facilities conditions, over time. Investment strategies that fail to account for existing backlog result in growing future liabilities and, ultimately, premature replacement of assets. Investment allocations based on commonly used formula methods do not account for existing backlog, nor do they match system renewal needs as they come due. The application of formula based methods results in an extremely erratic condition posture over time. Funding renewal requirements as they come due appears to be the more manageable approach from a condition perspective; however, this approach is difficult to execute from a budgeting perspective, where the stability of level funding is often preferred. The level of existing backlog is an essential determinant of the facility replacement cycle, as it represents the starting point for further deterioration. As evidenced by the two application portfolios, greater levels of backlog result in lower replacement cycles and vice versa.

Discretionary Funding Investment Strategies. For both portfolios, each strategy reduced backlog over a 5-year and 10-year pace to levels that prevented the replacement threshold from being reached in less than 50 years, even when the target backlog levels were not maintained. Strategies that did not maintain targeted condition values deteriorated more rapidly at higher condition index levels, since these higher levels are associated with larger volumes of backlog. Strategies that did maintain targeted condition values required substantially less investment after reaching the objective state of condition. The difference in levels of funding between strategies that simply achieved a target value and those that maintained the target value were less than 4.5% for Portfolio I (Fort Belvoir) and less than 2.2% for Portfolio II (Fort Stewart).

Investment Strategies with New Assets. Investment strategies that include the addition of new assets and the disposition of existing ones can dramatically affect facilities condition. Portfolio I (Fort Belvoir) improves from a baseline condition index of 0.39 to 0.04 by replacing the existing hospital and two outlying clinics with a new hospital, thereby eliminating some 87% of the existing backlog. Even without improving the remaining assets, the condition index of Portfolio I does not exceed 0.10 over 50 years. However, these strategies require some $10 million in equivalent annual funding over the short-term, while the maximum condition strategies that focus on existing assets require roughly $7.7 million. In contrast, replacement facilities in Portfolio II (Fort Stewart) have a very limited impact on condition and effectively mirror the minimum and maximum boundary strategies. In this case, a new clinic replaces three existing clinics, which account for a negligible portion of the total backlog. While the effect on condition is similar to the boundary scenarios, the impact on equivalent annual investment is material. The strategies including the replacement clinic necessitate some $1.1 million more than the boundary strategies focusing on existing assets over the short-term.

Sensitivity of Results. All 26 investment scenarios were regenerated using different values for cash flow modeling variables and compared with the baseline, which used 3.2% for the real discount rate and 2.0% for the system deterioration rate. Scenarios were generated with an 8.0% real discount rate (holding all other variables constant) and generated again with a 10% deterioration rate (holding all other variables constant). The results for both portfolios were similar. First, changes in the discount rate had a marginal effect on both funding and condition. Second, the higher deterioration rate increased equivalent annual condition index values for those scenarios that did not contain backlog (mainly the minimum funding scenarios and discretionary funding scenarios that did not maintain target condition values); however, the rank order of investment strategies remained largely unchanged. Finally, funding levels increased at higher deterioration rates for those scenarios that carried some levels of backlog and maintained those levels over time. In fact, over long horizons it appears more cost effective to eliminate backlog completely, rather than maintaining levels of backlog.

6.2 Evaluation of Tool

The purpose of this research has been to develop a dynamic approach to facility investment strategy, which comprehensively considers assets, condition, and investment needs. The tool implements the financial modeling and evaluation stages of the approach, and is intended to support capital planning and investment decision-making. The tool integrates the investment needs and condition data from technical and functional facility assessments, as well as ongoing facility costs, within a scenario-based modeling environment, so that a number of "what-if" funding decisions can be evaluated with effects on condition over time. The output from the tool is a starting point for capital programming and budgeting, where projects are packaged, sources of funds are determined, and project delivery methods are considered. The baseline requirements that the tool builds upon must be updated after project execution to effectively validate financial decisions and condition models. The dynamic approach provides a necessary context for developing the decision support tool and a basis for further work. The tool is evaluated in terms of 1) how it enables facility investment strategy, 2) how it is currently limited, and 3) what is the extent of its applicability.

6.2.1 ENABLING FACILITY INVESTMENT STRATEGY

The tool allows the decision-maker to consider a number of strategic choices, such as: "How fast or slow to invest?" "What is the effect of consolidating and eliminating some facilities?" "When might a replacement or significant overhaul to facilities be expected?" "How much funding is needed to improve existing facilities?" Facility condition is the objective measure of how these variables impact the portfolio. Strategic variables can thus be explored in establishing different facility investment policies. The following policies were investigated in the analysis.

Boundaries of Investment Policy. The limits of minimizing funding versus maximizing condition at the fastest pace possible effectively bound the investment solution space. The disparity of funding can provide a starting point for budget negotiations.

Establishment of Replacement Policy. The decision-maker can establish a condition threshold, which when reached, signals a decisive point for major recapitalization or replacement of facilities. For example, the period in which backlog grows to some percentage (depending on the chosen policy) of portfolio replacement value is the effective replacement cycle. Thus, replacement policy considers both requirements and levels of funding. Traditionally this has been exclusively viewed from a funding perspective. Replacement policy was demonstrated in the minimum funding investigations.

Condition-Based Investment Policy. Condition-based investment policy is the most significant aspect of the approach. The decision-maker can target a preferred condition state over different time periods and determine requisite levels of funding, which effectively become the facility budget. Pace of investment is a significant variable, as well as the decision to maintain a targeted condition level once it is reached. Condition-based (requirements driven) funding policy was demonstrated in the discretionary funding investigation section.

Targeted Policy for Facilities or Portfolios. Condition-based policy enables the establishment of targeted policies for individual facilities or portfolios. On a broad scale, decision-makers can establish different levels of acceptable condition that corresponds with other strategic goals and initiatives. For example, portfolios that support critical mission objectives may be assigned target condition states at lower levels than portfolios that support other mission objectives.

Benchmarks for Capital Allocation. The objective condition index provides an effective means for capital allocation among facilities or portfolios. The condition index associated with recognized levels of backlog is useful for comparing the state of facilities or portfolios and guiding subsequent investment decisions. The index provides a transparent measure of present allocation decisions across facilities and over time, and thus serves as a potential “lever” for improving or disposing of various assets.

Acquisitions and Dispositions. The tool permits the exploration of changes to the existing mix of facilities. Current facilities and their effects on cash flows can be eliminated, and new facilities can be added. The impact of acquisitions and dispositions was investigated in the section that addressed new assets.

Comprehensive & Scalable View of Investment and Condition. The tool provides a scalable view of facilities, investment, and condition. Asset-based cash flows allow facilities to be treated individually or as a portfolio at any given organizational level. Investment is considered in terms of capital and operational funding, which is classified as *operations*, *sustainment*, *improvement*, and *development*. Investment is thus scalable from a total amount to these primary classes. Condition can be viewed comprehensively or in terms of its technical, functional, and capacity elements. In this way, the effect of strategies emphasizing one type of investment can be understood across different aspects of condition. The analysis emphasizes the comprehensive view of facilities, investment, and condition. However, Appendix D illustrates more detailed investment and condition considerations for select scenarios.

6.2.2 LIMITATIONS

The tool is limited primarily in terms of how it models future investment requirements, mainly those needs related to technical, functional, and capacity backlog. Interrelations among cash flows pose some limitations as well; these are discussed in section 3.5. Technical backlog is modeled as growing at a constant compounding rate, which is based on industry guidelines. To date there is no available literature that validates aggregated deterioration rates. Moreover, system deterioration likely increases at a faster rate for larger levels of backlog and therefore is not constant. The deterioration rate must be validated for each unique portfolio to improve the accuracy of forecasted results. It is also possible to adapt the current modeling approach so that a different deterioration rate is applied at different thresholds of condition. Such an approach overcomes the constant rate problem and may well improve the projection of future system requirements.

Functional and capacity backlog requirements are underestimated over long horizons. These requirements are modeled using currently identified corrections of functional and capacity shortfalls. Such requirements have a finite period of usefulness. While it is recognized that future assessments will undoubtedly produce new requirements or obviate those currently recognized, there is little to no general basis for forecasting investment responses to obsolescence. It may be possible to establish obsolescence rates for specific portfolios or types facilities. However, the modeling approach employed by the tool simply carries known unfunded requirements forward to later years without growth. In this way, functional and capacity conditions are static and not modeled dynamically.

The tool is currently focused on buildings. The systems level renewal models are designed exclusively for different types of buildings. In general, the integrative framework with associated investment and condition classes could be applied to any infrastructure asset. That is, roads, bridges and other asset classes may be considered in terms of *operations*, *sustainment*, *improvement*, and *development* or in terms of technical, functional, and capacity condition. However, the cost models used to generate and forecast investment needs are inevitably specific to the asset class being considered. Hence, the support tool currently models requirements for buildings only, although such models could be expanded to include the other types of infrastructure.

6.2.3 EXTENT OF APPLICABILITY

Although applied to (and to some degree developed for) a specific federal agency, the tool and framework are exportable to other public agencies and institutional owners. Agencies and owners that hold facilities over long horizons in locations that restrict dispositions in secondary markets share common infrastructure characteristics with the federal agency (U.S. Army) used as an application test-bed. Mainly, public and institutional owners are concerned with the facilities condition over the long run. Consequently, investment decisions pertaining to the maintenance, repair, and renewal of physical systems and the adaptation, alteration, and addition of functional configurations require increased emphasis. The tool and integrative framework provide a means for synthesizing this array of facility investment and for contemplating the effects of current funding decisions on future facility conditions. The integrative framework builds on generic classes of facility investment and types of facility condition that are broadly applicable to several different types of infrastructure assets. In addition, the tool is readily adapted to owners with varying degrees of condition assessment and cost modeling data.

Chapter 7 Conclusions, Implications & Future Work

7.1 Conclusions

7.1.1 ENHANCED DECISION MAKING DURING CAPITAL PLANNING

The principal conclusion from this research is that facility condition can provide an essential measure for guiding facility investment strategy. Investment strategies that are mindful of the potential condition outcome of current funding decisions provide a needed, but generally missing, complement to the capital decision-making environment. The analysis of two real facility portfolios demonstrates the impact of multiple funding decisions on future condition. Condition served as both the dependent measure of funding choices and the independent driver of requisite budgets. The analysis explored these interdependencies with 26 different scenarios for each portfolio and examined the disparity between funding and condition over different time horizons. In each scenario different outcomes were observed and contrasted.

Condition is not viewed as the final arbiter for selecting facility investment strategy. A number of social, political, economic, and environmental factors will influence the decision process and steer investment strategy on a different course. However, current and anticipated facility condition does provide an objective, stabilizing component to the process. A relevant example is provided in the analysis of Fort Belvoir, where a hospital replacement requires some \$10.6 million in annual funding over ten years. Recapitalizing the current hospital only requires an estimated \$7.6 million in annual funding over ten years. Each scenario results in roughly the same condition posture; however, for economic or other reasons the better decision may well be the seemingly more costly replacement hospital. Condition simply indicates that both are options for drastically improving the portfolio.

7.1.2 THE APPROACH IS FEASIBLE

A second conclusion is that the proposed approach and supporting tools are feasible for the application setting (U.S. Army Medical Department). The tool provides an effective means for synthesizing and analyzing condition, planning, and ongoing cost data that is generated by assessment tools and methods that are currently in place. The degree to which the approach actually influences budget decisions remains to be tested. Even if the approach does not "justify" increased levels of funding, it provides a starting point for allocating currently available discretionary dollars. Additionally, the extent to which baseline condition data can be updated by the execution process remains for evaluation. Efforts are underway to automate the linkage between the condition assessment information system and existing computerized maintenance management systems. The decision support tool effectively integrates available facility data in its current form without imposing additional data requirements and provides an economically robust methodology for evaluating multiple future possibilities. The tool is easily transported, as it is based on a Microsoft® platform. Its ease of use is relatively straightforward. Other users have experimented with the modeling and analytic portions of the tool with limited instruction. Populating the facility database is the most cumbersome aspect of the tool. Larger questions to be addressed relate to the level of detail and the content of facility information required for capital planning, as well as the frequency of its update. Currently, both technical and functional data are very detailed; the tool builds on this detail and provides a practical way of managing it. However, it may prove more economical to lessen the data requirements by focusing on critical facilities and/or systems.

7.1.3 FACILITY INVESTMENT STRATEGY IS PORTFOLIO UNIQUE

The analysis and scenario investigation leads to another conclusion: the unique composition of facility portfolios necessitates unique investment strategies. The analysis contrasted scenarios between two portfolios that were similar in scope, yet different in age and condition. The analysis showed that the portfolio in better condition (Fort Stewart) required less funding and provided a more stable condition posture over time. Additionally, the resulting replacement cycles from minimum funding scenarios were less dramatic for Fort Stewart. The life cycle costs of renewing physical systems and current backlog were the determinants of these differences. Life cycle costs were modeled as they occurred (i.e., they were "lumpy" over time).

An implication is that commonly used formula-based (incremental) budgeting practices are not well suited for matching actual facility requirements, nor do they address the unique backlog requirements of different portfolios. Simple age-based and square-foot-based budgeting formulas would fund the two portfolios studied at nearly equal levels. The result is enervating for Fort Belvoir, which is in a worse starting condition. However, in very large portfolios, system life cycle costs tend to average out. In the case of federal agencies with one-year budget cycles, the "law of large numbers" is the only way to effectively shift funds among smaller portfolios. The other option for employing formula-based approaches is to establish a sinking fund, which may be viable for public (at state or local levels) or institutional owners.

7.2 Implications

7.2.1 NEW DIRECTION FOR CAPITAL ALLOCATION POLICY

The approach developed and applied within this research has a broad implication for public capital planning and budgeting. Capital allocation can effectively be based on facility condition, which considers not only the physical nature of assets, but also the functionality of these assets. In effect, condition-based funding policy can be established that manages backlog and other requirements over time. A requirements-based approach to capital planning and budgeting would be a significant departure from incremental budgeting practices that are prevalent within all levels of government. With the tool developed, capital planners may target preferred condition postures for different portfolios or facilities. The level of financial commitment required over time can then be determined and a corresponding budget established. Capital planning can thus focus on the balance of condition and capital, while capital budgeting manages desired levels of condition. Allocation can then effectively address unique facility portfolio requirements. Additionally, portfolios of varying organizational significance can be targeted at different levels of condition.

The idea can be further extended to congressional capital allocation. The approach is suggestive of some devolution of authority, where federal agencies manage to condition. If Congress could see a way past the micro-management of military construction dollars on an annual basis, a process could unfold where federal asset managers are allocated a pool of discretionary dollars biennially (or over longer periods). Funds could then be focused on the *sustainment* and *improvement* of existing facilities or on the *development* of new facilities based on technical, functional, and capacity condition. Feedback (to Congress and the public) could then occur through an objective, condition-based asset report. Where investment commitment is not made, resulting facility condition can be anticipated and recorded as measure of transparency. There are methodological issues confronting condition assessment at a federal level, and these would need resolving; however, the financial-based condition indicator is a promising starting point for resolution. The condition indicator provides an absolute and relative measure of condition, so that requisite funding is readily discernable. Asset managers would also retain the discretion to establish what level of deteriorated facility value constitutes "adequacy."

7.2.2 STANDARD (OBJECTIVE) APPROACH TO ASSET ACCOUNTABILITY

Development of an approach with condition as a primary planning variable is auspicious due to recent changes in public capital accountability. Modifications to public financial reporting practices have elevated visibility of the value and liability of infrastructure assets, thereby increasing the role of condition data in the capital allocation and reporting process. The Governmental Accounting Standards Board (GASB) Statement No. 34 now requires state and local governments to report the value, depreciation, and condition of infrastructure assets. Governments must effectively shift to full accrual accounting practices and report all capital assets and long-term liabilities. Capital assets – buildings and infrastructure – must either be depreciated or actual costs and conditions accounted for as supplementary information (GASB 1999). The intent is to increase awareness of the true value and costs of government assets (Walters 1999). State and local governments must now begin to consider the current and future condition of their assets with financial implications.

At a federal level, the Statement of Federal Financial Accounting Standards (SFFAS) No. 6 requires agencies to report dollar estimates of deferred maintenance on financial statements and establish condition ratings for capital assets (FASAB 1996). Effective 1998, nine federal agencies were required to begin implementation of this standard. Interestingly, only four of the nine were confident in timely implementation and only two had previously conducted comprehensive surveys of backlog. The problems facing implementation are real and pertain mainly to the methodology and cost (GAO 1998). However, the implication is that federal decision-makers are now realizing the value in understanding the hidden cost of years of previously deferred requirements. Both GASB Statement No. 34 and SFFAS No. 6 compel a pervasive need for methods and tools that support public decision-makers in balancing facilities condition and levels of financial commitment. This research provides an objective methodology for addressing these needs.

7.2.3 BARRIERS TO IMPLEMENTATION

Facility investment strategy is based on firm, fixed commitments to funding at determined levels. Managing to condition requires consistent and adequate levels of funding. However, past decades have proven this not to be a viable strategy at all levels of government. Policy makers and budget decisions have consistently transferred funds from facility sustainment accounts to cover shortfalls in other operational areas. A notable example comes from the U.S. Army Vice Chief of Staff: “The Army is providing 70 percent of the money it needs to maintain its plumbing, sewers, buildings, streets, etc…’We’re robbing people on those facilities.’” (AUSA 2001). Adequate funding for infrastructure is a fundamental structural problem in all levels of government, and there are no simple solutions. However, the approach developed in this research may provide a step toward better allocation of the limited resources that are available.

The approach is predicated on knowledge of assets. Condition assessments, as well functional assessments that align assets with organizational strategy, are the foundation of this understanding. Both processes are time consuming and expensive, and the cost rises with greater levels of detail. In addition, for large portfolios it is imperative that these processes be employed with consistency to provide meaningful comparative data. Employing the approach on a wide-scale basis will necessitate prioritization of efforts. That is, critical portfolios or facilities are examined at the expense of others. Additionally, a reliability-centered approach for assessing building systems may lessen the data burden. The National Research Council makes recommendations for restructuring and reprioritizing assessment practices at a federal level (NRC 1998). For state and local governments and institutional owners, technical and functional assessments may prove a daunting fiscal challenge. However, some level of information about facilities condition and needs is imperative for capital planning to be effective.

Knowledge of assets also extends to financial management systems. Asset-based cash flows provide a foundation for developing and evaluating facility investment strategies that are scalable across different collections of assets. Accounting and budgeting systems that consider facilities as critical components of overall public and institutional services and that account for investment needs by asset are necessary for realizing the approach. As discussed in section 4.3.1, it was necessary to manipulate aggregated costs to derive asset-based costs for utilities and maintenance and repair. Financial management practices at the federal level are currently inadequate to support effective capital allocation and decision making, and "…the Defense Department was singled out as one of the worst examples of financial mismanagement in the federal government" (Saldarini 2000b). Such obstacles can be overcome, as was done in this research by using source data; however, the accuracy of such costs will remain an open question until accounting and budgeting practices are improved. Similar financial reporting problems are prevalent among local and state governments (Wooldridge et al. 2000).

7.3 Future Work

The approach provides a platform for future work. First, and foremost, application on a broader scale is necessary for further validation of modeling assumptions. This research addressed 2 of the 32 health facility portfolios located at major Army installations. Several initiatives are planned to implement the approach and supporting tools on a larger scale within the Army Medical Department. The next step will involve a regional application in Europe, where three major health care systems, accounting for some $1 billion in replacement value, are fed by a number of dispersed campuses. The intent is to verify the extent to which the approach and tool can support capital allocation and condition-based investment strategy in practice on a broader scale. Following this regional application, a wide-scale application is proposed to address all Army medical regions. Future capital planners and decision-makers may well be equipped to develop condition-based investment strategy at multiple levels, from the entire health facility portfolio, to regions, to facilities.

Implementation at this level will require modifications to the decision support tool. In current form, it is a locally resident system that requires manual input of data. A more sophisticated client-server application will be needed for wide-scale application. An internet-based application that draws data from existing condition assessment systems, computerized maintenance management systems, and master planning systems automatically is envisioned. The prototype tool provides a structure and methodology for this implementation.

The tool would also benefit by incorporating sources of funding. Resulting funding schemes from the model could then be matched with available sources. The intent of the tool is to devise strategies based on *operations*, *sustainment*, *investment*, and *development*, so as not to be skewed by the plethora of funding programs that exist within the Department of Defense. However, after a given strategy is developed, matching sources of funding for capital programming and budgeting purposes would provide a useful enhancement.

A significant portion of this research focused on facility cost modeling, and the tool was structured in the most robust fashion possible within the constraints of time. However, a number of modeling enhancements and cash flow interrelationships are possible. First, modeling the relationship between maintenance and repair and system renewal would be a useful addition. This might be accomplished simply by devising ranges of expected service life based on different levels of maintenance and repair. Moreover, the system-based renewal model is not validated, nor is the aggregated rate of deterioration. Feedback from project execution and reassessed requirements needs to be incorporated in these models to improve their accuracy. Second, the linkages between *improvement* projects and their impact on operations costs were not examined in this research. It would be interesting to incorporate the operational effect of improving systems and altering spaces within the overall analysis.

Condition indicators provide a very useful benchmark for characterizing the technical and functional aspects of facilities; however, they are currently isolated metrics. That is, they are not correlated with tangible benefits and costs, which impact the bottom line of an organization. The utility of these metrics and the effect they have on capital allocation may be enhanced if there were a correlation between “poor” condition indices and organizational performance, cost, revenue, safety, and reliability (to name a few). For example, a hospital with a high technical condition index and/or a high functional condition index may be associated with higher rates of accreditation problems, longer bed stays, or overstaffing. Furthermore, the condition indicator would provide greater benefit if benchmarks could be established between other military services, public/non-profit health systems, and private health systems. Benchmarking the success of like organizations with varying states of facility conditions would be of great value for assigning condition ratings, such as “poor,” “fair,” or “good,” to select index ranges.

The extent to which the approach actually influences budgeting and investment decisions is a long-term effort, one that is reserved for future application and testing. The approach proposed by this research is a starting point for improving the management of facilities and the allocation of capital.

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Appendix A. Glossary of Terms

Backlog: Generally refers to the identified funding requirements associated with the technical (e.g. maintenance, repair, and renewal) and functional (e.g. upgrades and alterations) aspects of a facility that remain unfunded or are deferred beyond the period of recognized need.

Capacity Backlog: The collection of *development* (additions and new) projects identified to address shortfalls in capacity.

Capacity Condition: The condition of a facility specifically associated with *capacity backlog*.

Condition: In general, the state of a facility measured by current levels of *backlog* (in dollar terms) over *current replacement value*.

Current Replacement Value: The cost of replacing a facility in-kind based on current construction costs.

Deferred Maintenance: See Backlog.

Deficiencies: See Backlog.

Development: An *investment* in the addition to or the replacement of a facility in-place or the construction of a new facility.

Facility Systems: The physical systems, sub-systems, and components that comprise a facility. Examples include the structural, closure, and roofing systems that constitute the shell of the facility and the mechanical, electrical, and plumbing systems that provide the internal environment.

Facility: Generally refers to a building throughout this dissertation. In the broader civil engineering context, facility connotes any constructed physical structure, such as a roadway, water treatment plant, bridge, etc.

Functional Backlog: The collection of *improvement* (upgrades and alterations) projects intended to remedy the functional shortcomings of a facility. Functional backlog generally relates to building space, which is often classified as rooms, departments, floors, or circulation. Building space is improved when it no longer serves its intended purpose or no longer supports the operations conducted within. Functional backlog also refers to requirements that enhance the current level of performance or service of a system.

Functional Condition: The condition of a facility specifically associated with *functional backlog*.

Improvement: An *investment* in the upgrade or alteration of spaces or systems in response to changes in use, technology, etc.

Infrastructure Asset: A physical facility or structure (e.g., a building) used in supporting or providing a public or private service.

Investment: *Capital* and *operational* funding applied to infrastructure assets. *Capital* refers to large one-time expenditures that may be depreciated over longer periods of time. *Operational* funding is the ongoing (or recurring) expenditure associated with operating and maintaining an infrastructure asset.

Operations: An *investment* in the ongoing expenses associated with operating and using an infrastructure asset. In the case of a building, such investment refers to utility expenses and utilization costs (i.e., personnel salaries, benefits, supplies, equipment, etc.).

Portfolio: A collection of infrastructure assets or facilities. Also refers to the aggregate of different types of investment and condition associated with facilities.

Sustainment: An *investment* in the maintenance, repair, or renewal of physical systems.

Technical Backlog: The maintenance, repair, and renewal requirements that are deferred (or not funded) beyond the projected period of need. Technical backlog relates to facility systems, sub-systems, and components.

Technical Condition: The condition of a facility specifically associated with *technical backlog*.

Appendix B. The Prototype Tool

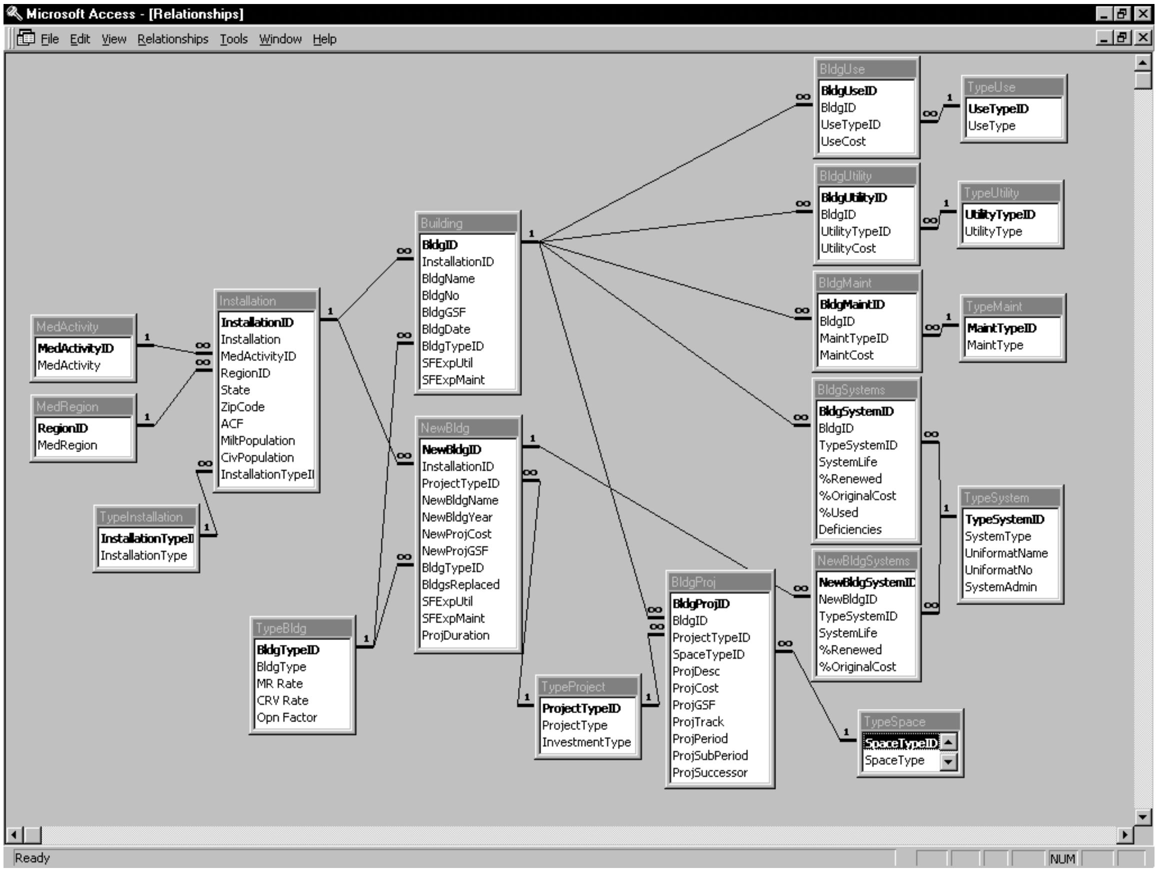
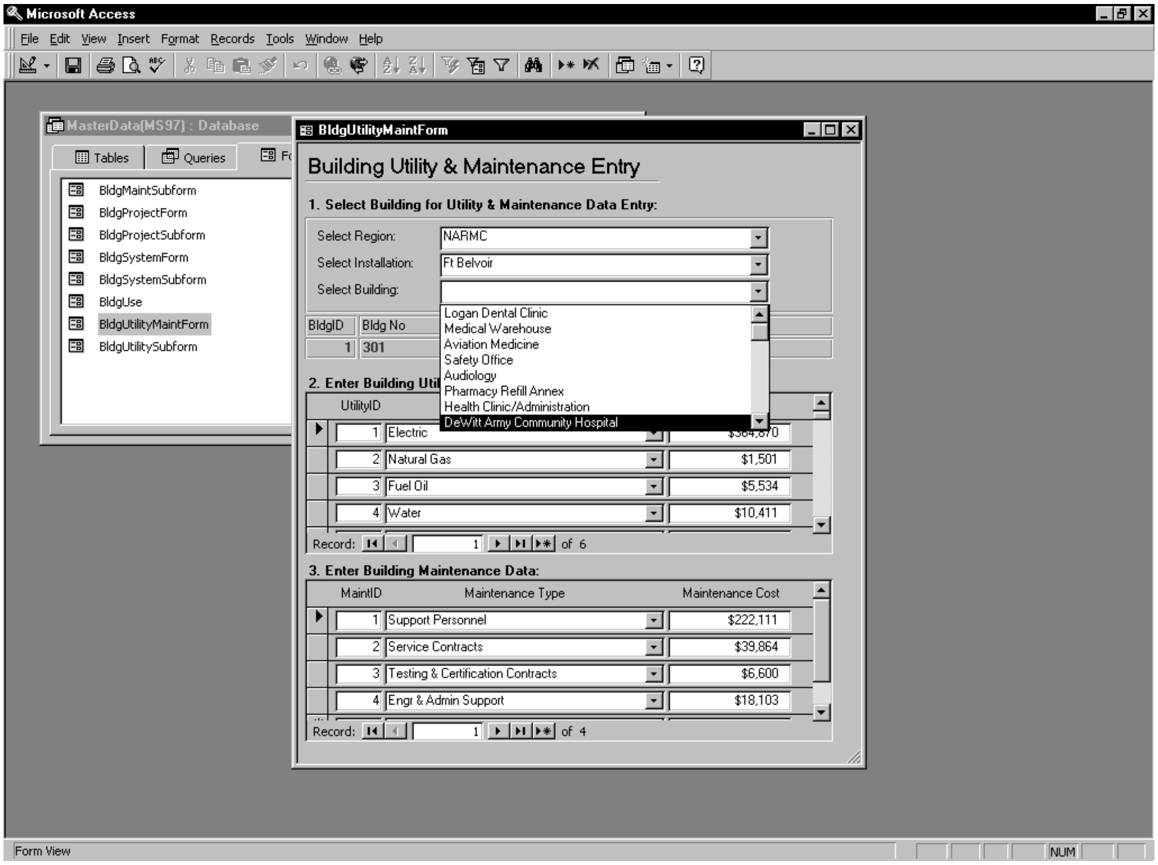


Figure B-1 Screen Shot of Database Relationships



Building Utility & Maintenance Entry

1. Select Building for Utility & Maintenance Data Entry:

Select Region: NARMC
Select Installation: Ft Belvoir
Select Building:

- Logan Dental Clinic
- Medical Warehouse
- Aviation Medicine
- Safety Office
- Audiology
- Pharmacy Refill Annex
- Health Clinic/Administration
- DeWitt Army Community Hospital

BldgID	Bldg No
1	301

2. Enter Building Util

UtilityID		
1	Electric	$364,870
2	Natural Gas	$1,501
3	Fuel Oil	$5,534
4	Water	$10,411

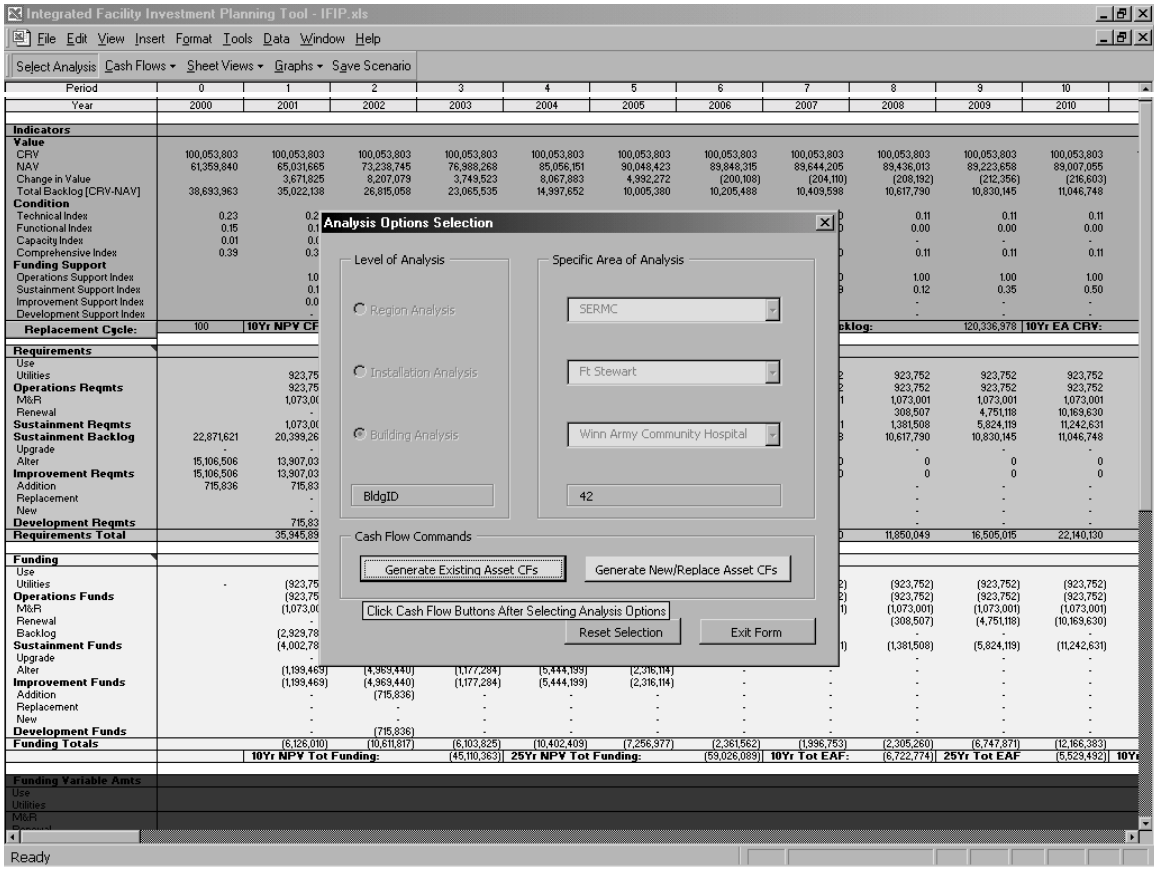
Record: 1 of 6

3. Enter Building Maintenance Data:

MaintID	Maintenance Type	Maintenance Cost
1	Support Personnel	$222,111
2	Service Contracts	$39,864
3	Testing & Certification Contracts	$6,600
4	Engr & Admin Support	$18,103

Record: 1 of 4

Figure B-2 Screen Shot Demonstrating Scalability in Selecting a Facility



Analysis Options Selection

Level of Analysis

○ Region Analysis
○ Installation Analysis
● Building Analysis

BldgID

Specific Area of Analysis

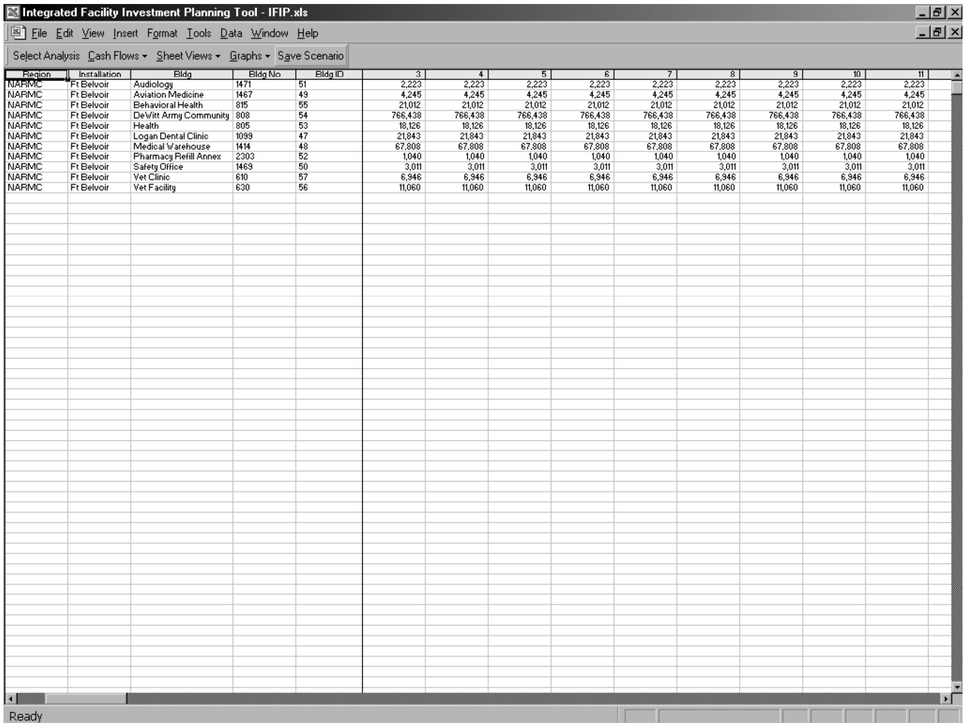
SERMC
Ft Stewart
Winn Army Community Hospital
42

Cash Flow Commands

Click Cash Flow Buttons After Selecting Analysis Options

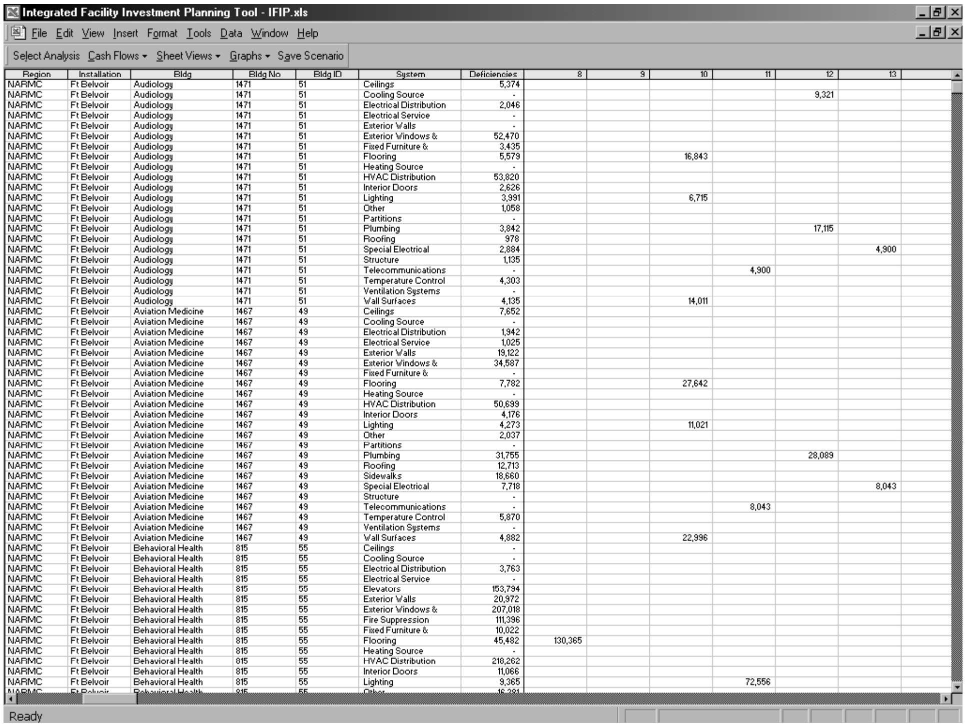
Period	0	1	2	3	4	5	6	7	8	9	10
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Indicators											
Value											
CRV	100,053,803	100,053,803	100,053,803	100,053,803	100,053,803	100,053,803	100,053,803	100,053,803	100,053,803	100,053,803	100,053,803
NAV	61,359,840	65,031,665	73,238,745	76,988,268	85,056,151	90,048,423	89,848,315	89,644,205	89,436,013	89,223,658	89,007,055
Change in Value		3,671,825	8,207,079	3,749,523	8,067,883	4,992,272	(200,108)	(204,110)	(208,192)	(212,356)	(216,603)
Total Backlog [CRV-NAV]	38,693,963	35,022,138	26,815,058	23,065,535	14,997,652	10,005,380	10,205,488	10,409,598	10,617,790	10,830,145	11,046,748
Condition											
Technical Index	0.23	0.2							0.11	0.11	0.11
Functional Index	0.15	0.1							0.00	0.00	0.00
Capacity Index	0.01	0.0							-	-	-
Comprehensive Index	0.39	0.3							0.11	0.11	0.11
Funding Support											
Operations Support Index		1.0							1.00	1.00	1.00
Sustainment Support Index		0.1							0.12	0.35	0.50
Improvement Support Index		0.0							-	-	-
Development Support Index		-							-	-	-
Replacement Cycle:	100	**10Yr NPV CF**							**cklog:**	120,336,978	**10Yr EA CRV:**
Requirements											
Use											
Utilities		923,75							923,752	923,752	923,752
Operations Reqmts		923,75							923,752	923,752	923,752
M&R		1,073,00							1,073,001	1,073,001	1,073,001
Renewal		-							308,507	4,751,118	10,169,630
Sustainment Reqmts		1,073,00							1,381,508	5,824,119	11,242,631
Sustainment Backlog	22,871,621	20,399,26							10,617,790	10,830,145	11,046,748
Upgrade	-	-							-	-	-
Alter	15,106,506	13,907,03							0	0	0
Improvement Reqmts	15,106,506	13,907,03							0	0	0
Addition	715,836	715,83							-	-	-
Replacement		-							-	-	-
New		-							-	-	-
Development Reqmts		715,83							-	-	-
Requirements Total		35,945,89							11,850,049	16,505,015	22,140,130
Funding											
Use											
Utilities	-	(923,75							(923,752)	(923,752)	(923,752)
Operations Funds		(923,75							(923,752)	(923,752)	(923,752)
M&R		(1,073,00							(1,073,001)	(1,073,001)	(1,073,001)
Renewal		-							(308,507)	(4,751,118)	(10,169,630)
Backlog		(2,929,78							-	-	-
Sustainment Funds		(4,002,78							(1,381,508)	(5,824,119)	(11,242,631)
Upgrade		-							-	-	-
Alter		(1,199,469)	(4,969,440)	(1,177,284)	(5,444,199)	(2,316,114)	-	-	-	-	-
Improvement Funds		(1,199,469)	(4,969,440)	(1,177,284)	(5,444,199)	(2,316,114)	-	-	-	-	-
Addition		-	(715,836)	-	-	-	-	-	-	-	-
Replacement		-	-	-	-	-	-	-	-	-	-
New		-	-	-	-	-	-	-	-	-	-
Development Funds		-	(715,836)	-	-	-	-	-	-	-	-
Funding Totals		(6,126,010)	(10,611,817)	(6,103,825)	(10,402,409)	(7,256,977)	(2,361,562)	(1,996,753)	(2,305,260)	(6,747,871)	(12,166,383)
		10Yr NPV Tot Funding:		(45,110,363)	**25Yr NPV Tot Funding:**		(59,026,089)	**10Yr Tot EAF:**	(6,722,774)	**25Yr Tot EAF**	(5,529,492)
Funding Variable Amts											
Use											
Utilities											
M&R											

Figure B-3 Screen Shot of Form for Selecting Level of Analysis



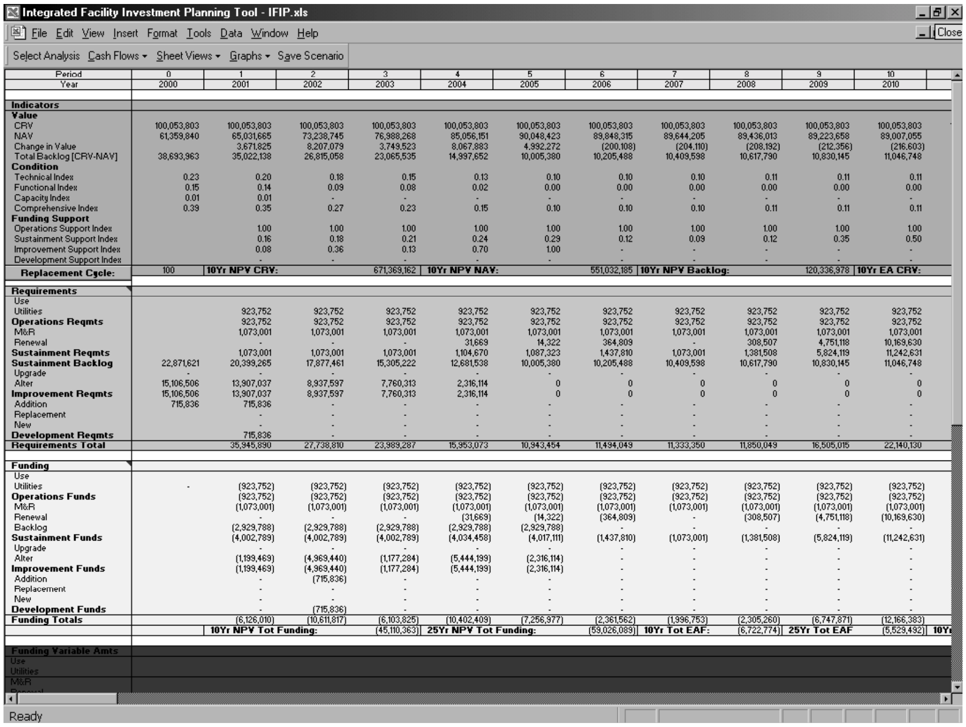
Region	Installation	Bldg	Bldg No	Bldg ID	3	4	5	6	7	8	9	10	11
NARMC	Ft Belvoir	Audiology	1471	51	2,223	2,223	2,223	2,223	2,223	2,223	2,223	2,223	2,223
NARMC	Ft Belvoir	Aviation Medicine	1467	49	4,245	4,245	4,245	4,245	4,245	4,245	4,245	4,245	4,245
NARMC	Ft Belvoir	Behavioral Health	815	55	21,012	21,012	21,012	21,012	21,012	21,012	21,012	21,012	21,012
NARMC	Ft Belvoir	DeWitt Army Community	808	54	766,438	766,438	766,438	766,438	766,438	766,438	766,438	766,438	766,438
NARMC	Ft Belvoir	Health	805	53	18,126	18,126	18,126	18,126	18,126	18,126	18,126	18,126	18,126
NARMC	Ft Belvoir	Logan Dental Clinic	1099	47	21,843	21,843	21,843	21,843	21,843	21,843	21,843	21,843	21,843
NARMC	Ft Belvoir	Medical Warehouse	1414	48	67,808	67,808	67,808	67,808	67,808	67,808	67,808	67,808	67,808
NARMC	Ft Belvoir	Pharmacy Refill Annex	2303	52	1,040	1,040	1,040	1,040	1,040	1,040	1,040	1,040	1,040
NARMC	Ft Belvoir	Safety Office	1469	50	3,011	3,011	3,011	3,011	3,011	3,011	3,011	3,011	3,011
NARMC	Ft Belvoir	Vet Clinic	610	57	6,946	6,946	6,946	6,946	6,946	6,946	6,946	6,946	6,946
NARMC	Ft Belvoir	Vet Facility	630	56	11,060	11,060	11,060	11,060	11,060	11,060	11,060	11,060	11,060

Figure B-4 Screen Shot of Worksheet with Asset-Based Utility Cash Flows



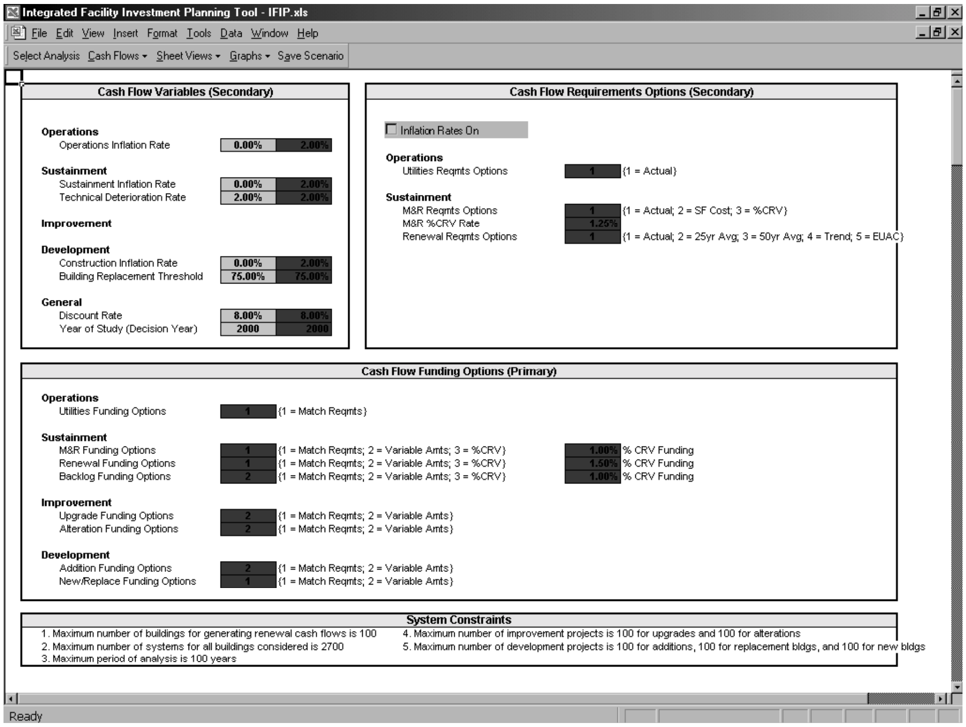
Region	Installation	Bldg	Bldg No	Bldg ID	System	Deficiencies	8	9	10	11	12	13
NARMC	Ft Belvoir	Audiology	1471	51	Ceilings	5,374						
NARMC	Ft Belvoir	Audiology	1471	51	Cooling Source	-					9,321	
NARMC	Ft Belvoir	Audiology	1471	51	Electrical Distribution	2,046						
NARMC	Ft Belvoir	Audiology	1471	51	Electrical Service	-						
NARMC	Ft Belvoir	Audiology	1471	51	Exterior Walls	-						
NARMC	Ft Belvoir	Audiology	1471	51	Exterior Windows &	52,470						
NARMC	Ft Belvoir	Audiology	1471	51	Fixed Furniture &	3,435						
NARMC	Ft Belvoir	Audiology	1471	51	Flooring	5,579			16,843			
NARMC	Ft Belvoir	Audiology	1471	51	Heating Source	-						
NARMC	Ft Belvoir	Audiology	1471	51	HVAC Distribution	53,820						
NARMC	Ft Belvoir	Audiology	1471	51	Interior Doors	2,626						
NARMC	Ft Belvoir	Audiology	1471	51	Lighting	3,991			6,715			
NARMC	Ft Belvoir	Audiology	1471	51	Other	1,058						
NARMC	Ft Belvoir	Audiology	1471	51	Partitions	-						
NARMC	Ft Belvoir	Audiology	1471	51	Plumbing	3,842					17,115	
NARMC	Ft Belvoir	Audiology	1471	51	Roofing	978						
NARMC	Ft Belvoir	Audiology	1471	51	Special Electrical	2,884						4,900
NARMC	Ft Belvoir	Audiology	1471	51	Structure	1,135						
NARMC	Ft Belvoir	Audiology	1471	51	Telecommunications	-				4,900		
NARMC	Ft Belvoir	Audiology	1471	51	Temperature Control	4,303						
NARMC	Ft Belvoir	Audiology	1471	51	Ventilation Systems	-						
NARMC	Ft Belvoir	Audiology	1471	51	Wall Surfaces	4,135			14,011			
NARMC	Ft Belvoir	Aviation Medicine	1467	49	Ceilings	7,652						
NARMC	Ft Belvoir	Aviation Medicine	1467	49	Cooling Source	-						
NARMC	Ft Belvoir	Aviation Medicine	1467	49	Electrical Distribution	1,942						
NARMC	Ft Belvoir	Aviation Medicine	1467	49	Electrical Service	1,025						
NARMC	Ft Belvoir	Aviation Medicine	1467	49	Exterior Walls	19,122						
NARMC	Ft Belvoir	Aviation Medicine	1467	49	Exterior Windows &	34,587						
NARMC	Ft Belvoir	Aviation Medicine	1467	49	Fixed Furniture &	-						
NARMC	Ft Belvoir	Aviation Medicine	1467	49	Flooring	7,782			27,642			
NARMC	Ft Belvoir	Aviation Medicine	1467	49	Heating Source	-						
NARMC	Ft Belvoir	Aviation Medicine	1467	49	HVAC Distribution	50,699						
NARMC	Ft Belvoir	Aviation Medicine	1467	49	Interior Doors	4,176						
NARMC	Ft Belvoir	Aviation Medicine	1467	49	Lighting	4,273			11,021			
NARMC	Ft Belvoir	Aviation Medicine	1467	49	Other	2,037						
NARMC	Ft Belvoir	Aviation Medicine	1467	49	Partitions	-						
NARMC	Ft Belvoir	Aviation Medicine	1467	49	Plumbing	31,755					28,089	
NARMC	Ft Belvoir	Aviation Medicine	1467	49	Roofing	12,713						
NARMC	Ft Belvoir	Aviation Medicine	1467	49	Sidewalks	18,660						
NARMC	Ft Belvoir	Aviation Medicine	1467	49	Special Electrical	7,718						8,043
NARMC	Ft Belvoir	Aviation Medicine	1467	49	Structure	-						
NARMC	Ft Belvoir	Aviation Medicine	1467	49	Telecommunications	-				8,043		
NARMC	Ft Belvoir	Aviation Medicine	1467	49	Temperature Control	5,870						
NARMC	Ft Belvoir	Aviation Medicine	1467	49	Ventilation Systems	-						
NARMC	Ft Belvoir	Aviation Medicine	1467	49	Wall Surfaces	4,882			22,996			
NARMC	Ft Belvoir	Behavioral Health	815	55	Ceilings	-						
NARMC	Ft Belvoir	Behavioral Health	815	55	Cooling Source	-						
NARMC	Ft Belvoir	Behavioral Health	815	55	Electrical Distribution	3,763						
NARMC	Ft Belvoir	Behavioral Health	815	55	Electrical Service	-						
NARMC	Ft Belvoir	Behavioral Health	815	55	Elevators	153,794						
NARMC	Ft Belvoir	Behavioral Health	815	55	Exterior Walls	20,972						
NARMC	Ft Belvoir	Behavioral Health	815	55	Exterior Windows &	207,018						
NARMC	Ft Belvoir	Behavioral Health	815	55	Fire Suppression	111,396						
NARMC	Ft Belvoir	Behavioral Health	815	55	Fixed Furniture &	10,022						
NARMC	Ft Belvoir	Behavioral Health	815	55	Flooring	45,482	130,365					
NARMC	Ft Belvoir	Behavioral Health	815	55	Heating Source	-						
NARMC	Ft Belvoir	Behavioral Health	815	55	HVAC Distribution	218,262						
NARMC	Ft Belvoir	Behavioral Health	815	55	Interior Doors	11,066						
NARMC	Ft Belvoir	Behavioral Health	815	55	Lighting	9,365				72,556		

Figure B-5 Screen Shot of Worksheet with System Renewal Cash Flows



Period	0	1	2	3	4	5	6	7	8	9	10
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Indicators											
Value											
CRV	100,053,803	100,053,803	100,053,803	100,053,803	100,053,803	100,053,803	100,053,803	100,053,803	100,053,803	100,053,803	100,053,803
NAV	61,359,840	65,031,665	73,238,745	76,988,268	85,056,151	90,048,423	89,848,315	89,644,205	89,436,013	89,223,658	89,007,055
Change in Value		3,671,825	8,207,079	3,749,523	8,067,883	4,992,272	(200,108)	(204,110)	(208,192)	(212,356)	(216,603)
Total Backlog [CRV-NAV]	38,693,963	35,022,138	26,815,058	23,065,535	14,997,652	10,005,380	10,205,488	10,409,598	10,617,790	10,830,145	11,046,748
Condition											
Technical Index	0.23	0.20	0.18	0.15	0.13	0.10	0.10	0.10	0.11	0.11	0.11
Functional Index	0.15	0.14	0.09	0.08	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Capacity Index	0.01	0.01	-	-	-	-	-	-	-	-	-
Comprehensive Index	0.39	0.35	0.27	0.23	0.15	0.10	0.10	0.10	0.11	0.11	0.11
Funding Support											
Operations Support Index		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Sustainment Support Index		0.16	0.18	0.21	0.24	0.29	0.12	0.09	0.12	0.35	0.50
Improvement Support Index		0.08	0.36	0.13	0.70	1.00	-	-	-	-	-
Development Support Index		-	-	-	-	-	-	-	-	-	-
Replacement Cycle:	100	**10Yr NPV CRV:**		671,369,162	**10Yr NPV NAV:**		551,032,185	**10Yr NPV Backlog:**		120,336,978	**10Yr EA CRV:**
Requirements											
Use											
Utilities		923,752	923,752	923,752	923,752	923,752	923,752	923,752	923,752	923,752	923,752
Operations Reqmts		923,752	923,752	923,752	923,752	923,752	923,752	923,752	923,752	923,752	923,752
M&R		1,073,001	1,073,001	1,073,001	1,073,001	1,073,001	1,073,001	1,073,001	1,073,001	1,073,001	1,073,001
Renewal		-	-	-	31,669	14,322	364,809	-	308,507	4,751,118	10,169,630
Sustainment Reqmts		1,073,001	1,073,001	1,073,001	1,104,670	1,087,323	1,437,810	1,073,001	1,381,508	5,824,119	11,242,631
Sustainment Backlog	22,871,621	20,399,265	17,877,461	15,305,222	12,681,538	10,005,380	10,205,488	10,409,598	10,617,790	10,830,145	11,046,748
Upgrade	-	-	-	-	-	-	-	-	-	-	-
Alter	15,106,506	13,907,037	8,937,597	7,760,313	2,316,114	0	0	0	0	0	0
Improvement Reqmts	15,106,506	13,907,037	8,937,597	7,760,313	2,316,114	0	0	0	0	0	0
Addition	715,836	715,836	-	-	-	-	-	-	-	-	-
Replacement		-	-	-	-	-	-	-	-	-	-
New		-	-	-	-	-	-	-	-	-	-
Development Reqmts		715,836	-	-	-	-	-	-	-	-	-
Requirements Total		35,945,890	27,738,810	23,989,287	15,953,073	10,943,454	11,494,049	11,333,350	11,850,049	16,505,015	22,140,130
Funding											
Use											
Utilities	-	(923,752)	(923,752)	(923,752)	(923,752)	(923,752)	(923,752)	(923,752)	(923,752)	(923,752)	(923,752)
Operations Funds		(923,752)	(923,752)	(923,752)	(923,752)	(923,752)	(923,752)	(923,752)	(923,752)	(923,752)	(923,752)
M&R		(1,073,001)	(1,073,001)	(1,073,001)	(1,073,001)	(1,073,001)	(1,073,001)	(1,073,001)	(1,073,001)	(1,073,001)	(1,073,001)
Renewal		-	-	-	(31,669)	(14,322)	(364,809)	-	(308,507)	(4,751,118)	(10,169,630)
Backlog		(2,929,788)	(2,929,788)	(2,929,788)	(2,929,788)	(2,929,788)	-	-	-	-	-
Sustainment Funds		(4,002,789)	(4,002,789)	(4,002,789)	(4,034,458)	(4,017,111)	(1,437,810)	(1,073,001)	(1,381,508)	(5,824,119)	(11,242,631)
Upgrade		-	-	-	-	-	-	-	-	-	-
Alter		(1,199,469)	(4,969,440)	(1,177,284)	(5,444,199)	(2,316,114)	-	-	-	-	-
Improvement Funds		(1,199,469)	(4,969,440)	(1,177,284)	(5,444,199)	(2,316,114)	-	-	-	-	-
Addition		-	(715,836)	-	-	-	-	-	-	-	-
Replacement		-	-	-	-	-	-	-	-	-	-
New		-	-	-	-	-	-	-	-	-	-
Development Funds		-	(715,836)	-	-	-	-	-	-	-	-
Funding Totals		(6,126,010)	(10,611,817)	(6,103,825)	(10,402,409)	(7,256,977)	(2,361,562)	(1,996,753)	(2,305,260)	(6,747,871)	(12,166,383)
		10Yr NPV Tot Funding:		(45,110,363)	**25Yr NPV Tot Funding:**		(59,026,089)	**10Yr Tot EAF:**	(6,722,774)	**25Yr Tot EAF**	(5,529,492)
Funding Variable Amts											
Use											
Utilities											
M&R											

Figure B-6 Screen Shot of Portfolio Summary Worksheet



Cash Flow Variables (Secondary)

Operations		
Operations Inflation Rate	0.00%	2.00%
Sustainment		
Sustainment Inflation Rate	0.00%	2.00%
Technical Deterioration Rate	2.00%	2.00%
Improvement		
Development		
Construction Inflation Rate	0.00%	2.00%
Building Replacement Threshold	75.00%	75.00%
General		
Discount Rate	8.00%	8.00%
Year of Study (Decision Year)	2000	2000

Cash Flow Requirements Options (Secondary)

☐ Inflation Rates On

Operations		
Utilities Reqmts Options	1	{1 = Actual}
Sustainment		
M&R Reqmts Options	1	{1 = Actual; 2 = SF Cost; 3 = %CRV}
M&R %CRV Rate	1.25%	
Renewal Reqmts Options	1	{1 = Actual; 2 = 25yr Avg; 3 = 50yr Avg; 4 = Trend; 5 = EUAC}

Cash Flow Funding Options (Primary)

Operations				
Utilities Funding Options	1	{1 = Match Reqmts}		
Sustainment				
M&R Funding Options	1	{1 = Match Reqmts; 2 = Variable Amts; 3 = %CRV}	1.00%	% CRV Funding
Renewal Funding Options	1	{1 = Match Reqmts; 2 = Variable Amts; 3 = %CRV}	1.50%	% CRV Funding
Backlog Funding Options	2	{1 = Match Reqmts; 2 = Variable Amts; 3 = %CRV}	1.00%	% CRV Funding
Improvement				
Upgrade Funding Options	2	{1 = Match Reqmts; 2 = Variable Amts}		
Alteration Funding Options	2	{1 = Match Reqmts; 2 = Variable Amts}		
Development				
Addition Funding Options	2	{1 = Match Reqmts; 2 = Variable Amts}		
New/Replace Funding Options	1	{1 = Match Reqmts; 2 = Variable Amts}		

System Constraints

1. Maximum number of buildings for generating renewal cash flows is 100
2. Maximum number of systems for all buildings considered is 2700
3. Maximum period of analysis is 100 years
4. Maximum number of improvement projects is 100 for upgrades and 100 for alterations
5. Maximum number of development projects is 100 for additions, 100 for replacement bldgs, and 100 for new bldgs

Figure B-7 Screen Shot of Cash Flow Variables Worksheet

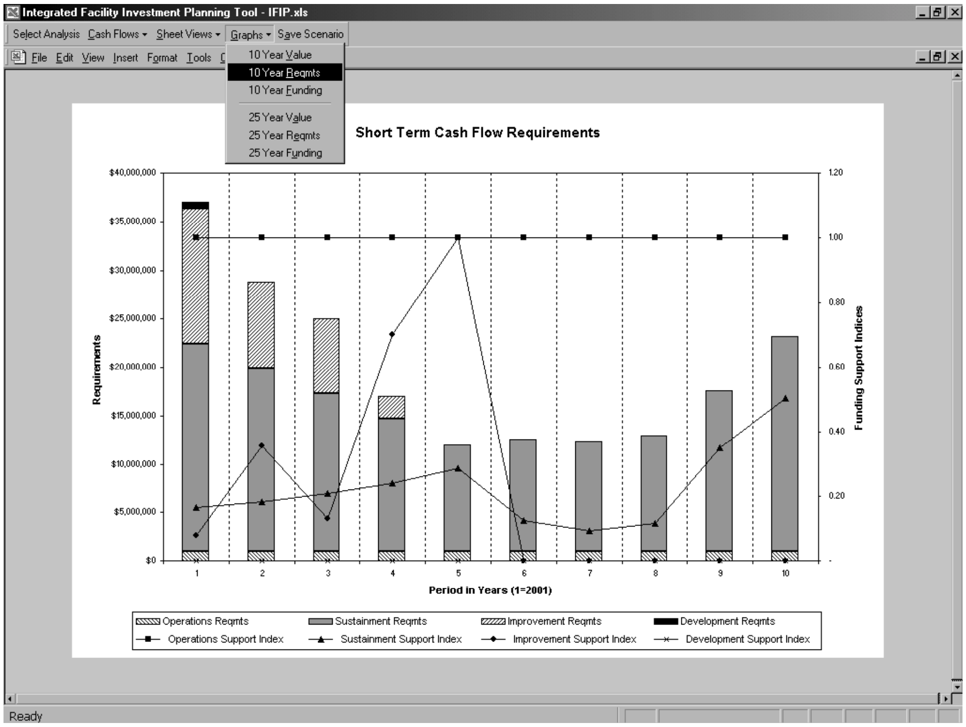


Figure B-8 Screen Shot of Short-Term Facility Requirements

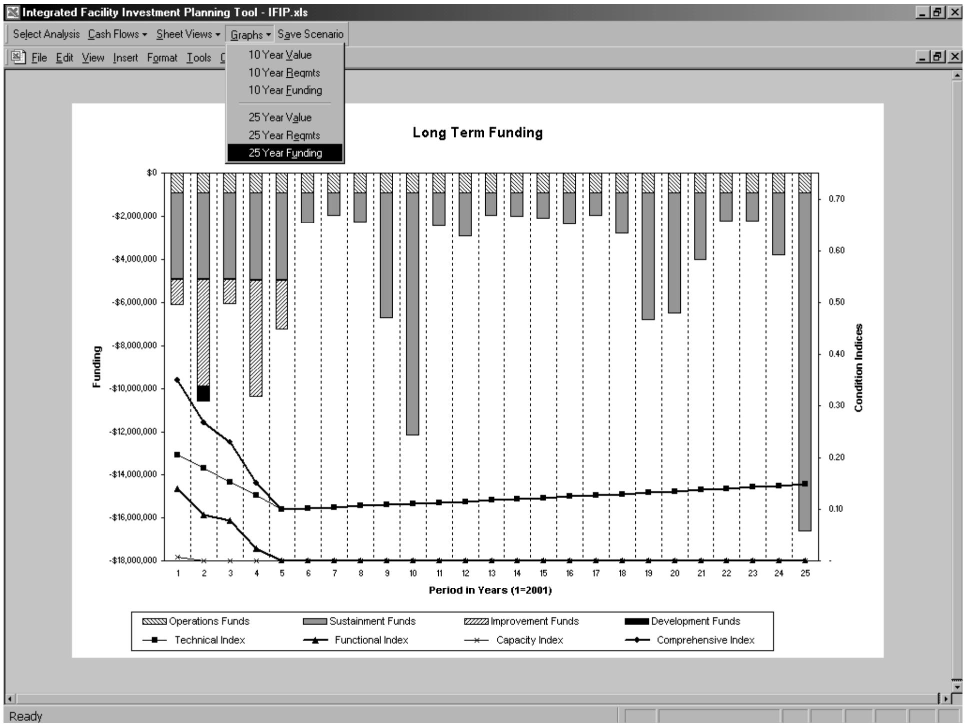


Figure B-9 Screen Shot of long-term Facility Funding

Appendix C. Application Portfolio Data

Installation	Building Name	Building No.	Gross Square Feet	Current Replacement Value	Age (Years)	Building Type
Ft Stewart	Administration Building	303	3,750	$567,365	7	Administration
Ft Stewart	Energy Support Building	350	8,100	$1,494,523	17	Central Energy
Ft Stewart	Dental Clinic #4	2115	15,241	$3,412,017	21	Dental Clinic
Ft Stewart	Dental Clinic #5	251	1,340	$299,987	66	Dental Clinic
Ft Stewart	Dental Clinic #1	440	18,855	$4,221,086	20	Dental Clinic
Ft Stewart	Winn Army Hospital	302	332,549	$85,083,486	17	Hospital
Ft Stewart	Mental Health Clinic	301	4,750	$864,732	7	Medical Clinic
Ft Stewart	Health Clinic (SFHC #2)	612	5,298	$964,495	21	Medical Clinic
Ft Stewart	Health Clinic (SFHC #1)	701	6,061	$1,103,398	23	Medical Clinic
Ft Stewart	Health Clinic (SFHC #3)	816	6,719	$1,223,186	22	Medical Clinic
Ft Stewart	Health/Dental Clinic (HAAF)	PID41456	58,502	$10,650,224	0	Medical Clinic
Ft Stewart	Medical Warehouse	306	9,000	$763,867	18	Medical Warehouse
Ft Stewart	Vet Clinic (HAAF)	1030	3,914	$712,539	48	Veterinary Facility
Ft Stewart	Vet Clinic	1180	3,362	$612,048	21	Veterinary Facility
Ft Stewart	Vet Offices	1182	2,813	$512,103	21	Veterinary Facility
Ft Belvoir	Safety Office	1469	3,475	$608,106	61	Administration
Ft Belvoir	Audiology	1471	2,566	$449,036	43	Administration
Ft Belvoir	Logan Dental Clinic	1099	13,272	$3,436,586	30	Dental Clinic
Ft Belvoir	DeWitt Army Hospital	808	260,245	$77,013,199	43	Hospital
Ft Belvoir	Pharmacy Refill Annex	2303	800	$202,595	1	Laboratory
Ft Belvoir	Aviation Medicine	1467	3,500	$736,969	61	Medical Clinic
Ft Belvoir	Health Clinic/Administration	805	14,948	$3,147,489	41	Medical Clinic
Ft Belvoir	Behavioral Health Services	815	17,328	$3,648,628	42	Medical Clinic
Ft Belvoir	Medical Warehouse	1414	78,282	$7,684,762	55	Medical Warehouse
Ft Belvoir	Vet Clinic	610	5,728	$1,206,102	7	Veterinary Facility
Ft Belvoir	Vet Facility	630	9,120	$1,920,331	56	Veterinary Facility

Figure C-1 Healthcare Facilities Inventory for Fort Stewart and Fort Belvoir

Installation	Building Name	Bldg No	Utility Cost	Historic M&R Cost	Budget M&R Cost	Deficiencies Cost
Ft Stewart	Administration Building	303	$2,544	$3,602	$3,330	$23,065
Ft Stewart	Energy Support Building	350	$17,582	$24,891	$22,993	$212,583
Ft Stewart	Dental Clinic #1	440	$24,301	$34,403	$31,299	$967,879
Ft Stewart	Dental Clinic #4	2115	$19,643	$27,809	$25,300	$898,651
Ft Stewart	Dental Clinic #5	251	$1,726	$2,445	$2,224	$32,133
Ft Stewart	Winn Army Hospital	302	$766,979	$1,085,801	$943,974	$9,189,507
Ft Stewart	Health Clinic (SFHC #1)	701	$5,755	$8,149	$7,697	$199,173
Ft Stewart	Health Clinic (SFHC #2)	612	$5,031	$7,123	$6,728	$232,836
Ft Stewart	Health Clinic (SFHC #3)	816	$6,381	$9,033	$8,532	$212,078
Ft Stewart	Health/Dental Clinic (HAAF)	PID41456	$55,557	$78,652	$74,292	N/A
Ft Stewart	Mental Health Clinic	301	$4,511	$6,386	$6,032	$43,888
Ft Stewart	Medical Warehouse	306	$6,105	$8,643	$7,993	$237,342
Ft Stewart	Vet Clinic	1180	$3,192	$4,520	$4,269	$135,178
Ft Stewart	Vet Clinic (HAAF)	1030	$3,717	$5,262	$4,970	$294,884
Ft Stewart	Vet Offices	1182	$2,672	$3,781	$3,572	$225,921
Ft Belvoir	Audiology	1471	$2,223.00	$2,582.00	$2,635.80	$147,675
Ft Belvoir	Aviation Medicine	1467	$4,245.00	$4,930.00	$5,140.80	$214,895
Ft Belvoir	Behavioral Health Services	815	$21,012.00	$24,407.00	$25,451.37	$1,109,090
Ft Belvoir	DeWitt Army Hospital	808	$766,438.00	$890,270.00	$854,436.38	$17,770,759
Ft Belvoir	Health Clinic/Administration	805	$18,126.00	$21,056.00	$21,955.62	$775,631
Ft Belvoir	Logan Dental Clinic	1099	$21,843.00	$25,372.00	$25,482.24	$511,505
Ft Belvoir	Medical Warehouse	1414	$67,808.00	$78,763.00	$80,411.27	$2,132,388
Ft Belvoir	Pharmacy Refill Annex	2303	$1,040.00	$1,208.00	$2,626.56	$4,554
Ft Belvoir	Safety Office	1469	$3,011.00	$3,497.00	$3,569.52	$205,123
Ft Belvoir	Vet Clinic	610	$6,946.00	$8,069.00	$8,413.29	N/A
Ft Belvoir	Vet Facility	630	$11,060.00	$12,847.00	$13,395.46	N/A

Figure C-2 Healthcare Facilities Operations & Maintenance Data for Fort Stewart and Fort Belvoir

Installation	Building Name	Building No.	ProjectType	Project Description	Total Cost	Project GSF
Ft Belvoir	DeWitt Army Hospital	808	Alteration/Adaptation	Renovate existing Mother Baby unit	$1,199,469	6,999
Ft Belvoir	DeWitt Army Hospital	808	Alteration/Adaptation	Relocate OB/GYN clinic to 3d floor	$1,421,319	6,602
Ft Belvoir	DeWitt Army Hospital	808	Alteration/Adaptation	Renovate 5th floor wing B for Med Surg unit	$3,548,121	14,274
Ft Belvoir	DeWitt Army Hospital	808	Alteration/Adaptation	Renovate existing LDR - Phase I	$742,458	3,335
Ft Belvoir	DeWitt Army Hospital	808	Alteration/Adaptation	Relocate Command wing to 5th floor	$434,826	4,412
Ft Belvoir	DeWitt Army Hospital	808	Alteration/Adaptation	Renovate existing LDR - Phase II	$742,458	3,335
Ft Belvoir	DeWitt Army Hospital	808	Alteration/Adaptation	Renovate & expand ER/ECC into A wing	$2,385,627	11,237
Ft Belvoir	DeWitt Army Hospital	808	Alteration/Adaptation	Relocate	$2,316,114	10,915
Ft Belvoir	DeWitt Army Hospital	808	Alteration/Adaptation	Renovate	$2,316,114	10,915
Ft Belvoir	DeWitt Army Hospital	808	Addition	Construct addition for OB/GYN clinic	$715,836	2,500
Ft Belvoir	Replace Army Hospital		Replacement	Replace Building No. 808, 805, 815	$75,572,931	273,200
Ft Stewart	Winn Army Hospital	302	Alteration/Adaptation	Reconfigure LDR	$458,490	2,750
Ft Stewart	Winn Army Hospital	302	Alteration/Adaptation	Renovate Food Service	$217,413	1,500
Ft Stewart	Winn Army Hospital	302	Alteration/Adaptation	Reconfigure and consolidate Pharmacy	$641,886	4,343
Ft Stewart	Winn Army Hospital	302	Alteration/Adaptation	Renovate Mammography	$269,178	1,236
Ft Stewart	Winn Army Hospital	302	Upgrade/Renovation	Relocate SDS to existing ICU	$251,430	1,700
Ft Stewart	Winn Army Hospital	302	Alteration/Adaptation	Renovate new PAD area	$286,926	2,000
Ft Stewart	Winn Army Hospital	302	Alteration/Adaptation	Reconfigure log whse for SW/BM	$1,169,889	11,966
Ft Stewart	Winn Army Hospital	302	Alteration/Adaptation	Relocate MCH to 4th Floor	$872,610	3,540
Ft Stewart	Winn Army Hospital	302	Alteration/Adaptation	Renovate Ob/Gyn clinic waiting	$667,029	4,000
Ft Stewart	Winn Army Hospital	302	Alteration/Adaptation	Renovate TRICARE area	$387,498	2,700
Ft Stewart	Winn Army Hospital	302	Alteration/Adaptation	Consolidate PM	$1,575,135	7,421
Ft Stewart	Winn Army Hospital	302	Alteration/Adaptation	Renovate PT/OT	$635,970	3,000
Ft Stewart	Winn Army Hospital	302	Alteration/Adaptation	Expand Pathology	$505,818	1,716
Ft Stewart	Winn Army Hospital	302	Alteration/Adaptation	Renovate Admin	$903,669	9,235
Ft Stewart	Winn Army Hospital	302	Upgrade/Renovation	Relocate Ortho	$96,135	663
Ft Stewart	Winn Army Hospital	302	Alteration/Adaptation	Create AMIC	$569,415	3,949
Ft Stewart	Winn Army Hospital	302	Alteration/Adaptation	Renovate Emergency	$1,019,031	6,890
Ft Stewart	Winn Army Hospital	302	Addition	Addition to Food Service	$578,289	3,153
Ft Stewart	Replace Health Clinic		Replacement	Replace Building No. 612, 701, 816	$10,600,000	48,881

Figure C-3 Healthcare Facilities Improvement and Development Projects for Fort Stewart and Fort Belvoir

Appendix D. Detailed Investment Allocation

This appendix is provided to highlight the balance of capital and condition on an annual basis. Whereas chapter 5 portrayed the results of several scenarios in terms of total funding and comprehensive condition, this appendix examines a few select scenarios in terms of *operations*, *sustainment*, *improvement*, and *development* funding and technical, functional, and capacity condition. The selected scenarios are chosen to illustrate how each emphasizes a specific type of investment and condition. For the sake of simplicity, only one portfolio (Fort Belvoir) is used as an example. The first scenario (Scenario 2 in chapter 5) maintains the current condition of the portfolio over a 50-year horizon. The second (Scenario 11 in chapter 5) recapitalizes existing assets to achieve an overall condition rating of 0.05 over a 5-year period and maintains that condition level over the long run. The third (Scenario 23 in chapter 5) replaces the existing hospital and two outlying clinics with a new hospital. In effect the first scenario (Scenario 2) simply preserves the "status quo" in condition terms. The latter two scenarios drastically improve portfolio condition by means of reinvestment (Scenario 11) and new investment (Scenario 23).

Figure D-1 displays the combined condition and funding for the first scenario (Scenario 2). Funding is arrayed on the left axis and is represented as negative values. Hence, levels of funding proceed from the top of the graph downward. Each type of funding (investment) is color coded (or cross-hatched) for differentiation. The stacked funding bars are in relative terms. That is, $1 million in *sustainment* funding is stacked on top of $1 million in *operations* funding and so on. Condition is represented on the right axis by different line markers to distinguish each unique type. Condition values proceed from the bottom of the graph upward. Condition index values are represented in absolute terms. Each figure shows annual funding and condition over a 25-year horizon beginning with year 2001.

Evident in Figure D-1, the only types of funding used in Scenario 2 include *operations* and *sustainment*. *Operations* is modeled as a level constant value, whereas, *sustainment* appears erratic due to "spikes" in system renewal funding. Clearly, even a "status quo" strategy requires significant capital outlays in years 2009, 2010, 2019, 2020, and 2025. However, over the initial eight years, some $2.5 million in annual funding will cover anticipated *operations* and *sustainment* requirements. It also apparent from the figure, that the funding strategy effectively maintains the current condition, as the lines representing the various condition types remain flat over time.

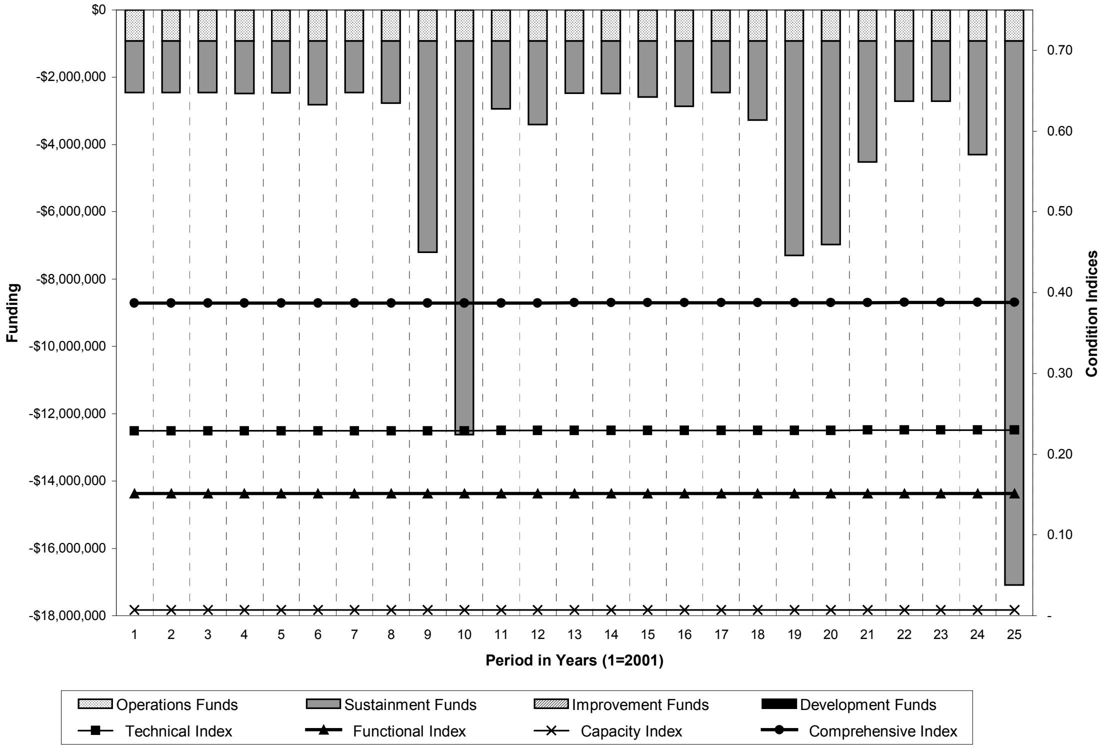


Figure D-1 Annual Funding and Condition for Maintaining Current Facility Condition

Figure D-2 reflects the annual funding and condition associated with recapitalizing existing facilities (Scenario 11). As in the former strategy, *operations* is level funded. *Sustainment* is also funded similarly to the "status quo" strategy; however, the first five years increase funding by over $3.4 million to reduce technical backlog. In addition, significant outlays are made in the initial five years in the form of *improvement* and *development* funding to remedy functional and capacity condition. The disparity of annual *improvement* funds represents the interdependencies of requirements that make up the functional backlog. The condition indices reflect the emphasis on recapitalization. The functional and capacity condition indices drop to zero by year 2005, while the technical condition index reduces to 0.05 and remains at that level through 2025 and beyond.

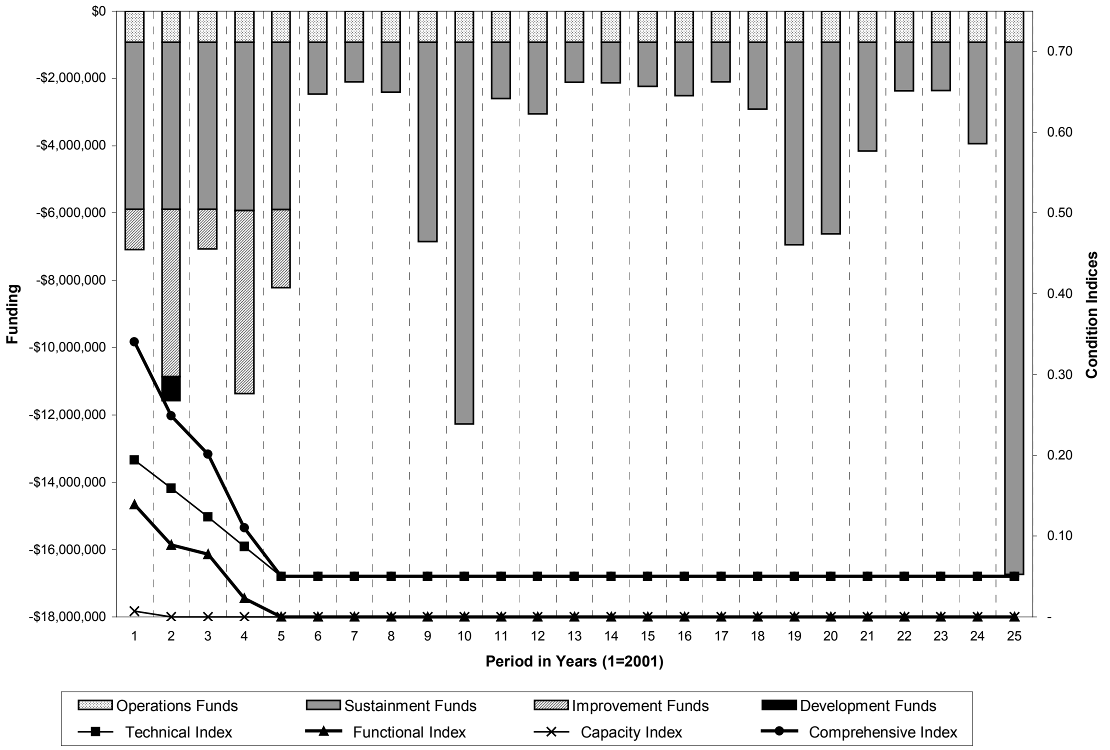


Figure D-2 Annual Funding and Condition for Recapitalizing the Facility Portfolio

The final investment strategy (Scenario 23) is much different than the first two. Shown in Figure D-3, this strategy effectively improves the portfolio condition by a large one-time investment in *development*. The *development* “spike” in year 2003 is indicative of the nearly $76 million hospital replacement. The scale of the funding axis skews the visual comparison with first two strategies; however, *operations* funding remains nearly the same with a nominal increase in 2006 after the new hospital is commissioned. *Sustainment* funding varies from the first strategies in that 87% of technical backlog is eliminated and the pattern of renewal requirements altered due to the addition of the new replacement hospital. No *improvement* funds are used in this strategy. The condition indices increase slightly up to the period when the replacement facility comes on line. At this point (year 2006), the functional and capacity condition indices are reduced to zero, while the technical condition index is reduced to 0.04. The latter index then increases subtly over time, as technical backlog is not funded for the remaining facilities.

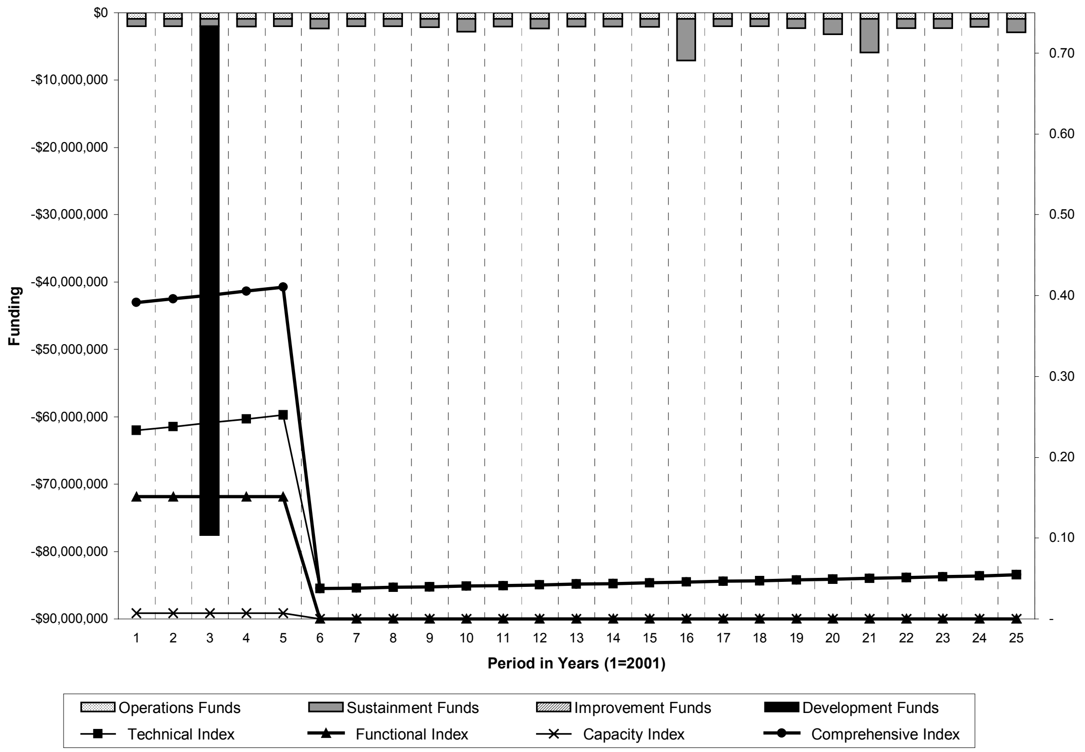


Figure D-3 Annual Funding and Condition for Replacing Existing Facilities

Each of the figures in this appendix illustrates how the different types of investment can be applied to achieve some level of desired condition. Each figure also illustrates the condition of the facility portfolio in terms of the technical, functional, and capacity aspects. Over the 25-year horizon, the facilities decision-maker is armed with an estimate of the annual level of funding associated with a given strategy and the impact of that funding on the condition of the facility portfolio. The appendix also illustrates the challenge of comparing alternative investment strategies on a period-by-period basis. This problem was addressed in chapter 5 using equivalent annual funding and the equivalent annual condition index.